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Superheating.

In view of the great interest taken in recent years in the application of superheated steam as an aid to the economical working of the steam engine and steam turbine, it is a matter of astonishment that our knowledge of its physical properties should be so vague and uncertain.

This, too, in spite of the fact that, since Regnault's classical series of experiments to determine the specific heat of superheated steam, many of the greatest among our experimentalists have conducted researches with the object of determining these properties.

In fact, as the results of successive experiments are published — each one differing from the last — our uncertainty as to exactly what are the true physical properties, becomes still more pronounced.

So far as our knowledge goes at present, the specific heat of superheated steam varies from about ·48 in the case of steam slightly superheated at low pressures, to ·7, or even more in the case of steam highly superheated at high pressures—say 120 lbs. per sq. in.

Different experimenters, however, differ in stating exactly how this variation takes place.

Professor J. A. Ewing, in a series of experiments carried out in 1897, found that the specific heat increases with the temperature at constant pressure.

This result was confirmed by Dr. J. Grindley in a series of experiments, communicated to the Royal Society by Professor Osborne Reynolds in 1900, who found that the specific heat is very approximately independent of the pressure and increases with the temperature.

On the other hand, Professor Carpenter, from an extensive series of experiments lasting from 1891-99, drew conclusions which are exactly opposite to these—namely that the specific heat is independent of the temperature for any given pressure, and increases with the pressure.

Professor Lorenz, in a recent series of experiments, on the other hand, concludes that the specific heat increases with the pressure, but decreases with an increase of temperature.

It is to be hoped that experiments now being carried out in the National Physical Laboratory, under the direction of Dr. Glazebrook, may throw much needed light on this question.

Fortunately, however, this uncertainty as to the precise physical properties of superheated steam does not matter greatly to the practical engineer, and is more important from the purely physical than from the engineering point of view. What the engineer does want to know is, how comes this superheating to cause economy, and how may superheating be best

applied. As to the first of these questions there seems to be much vagueness not only among engineers, but also among many of the writers in the columns of the technical press—a vagueness which can only be due to an incomplete understanding of the thermodynamics of the subject.

Now, when steam is superheated, an increase in volume takes place, the ratio of the volumes before and after superheating being very approximately proportional—except for very low degrees of superheat—to the absolute temperatures. If, then, other things were unaltered, the work done per lb. of steam would be proportional to the absolute temperature. However, with superheated steam, the expansion curve falls below that obtained with saturated steam, the index of expansion being 1·3 in the case of superheated steam, as against about 1.03 in the case of saturated steam, so that the work done is proportionately less with superheated than with saturated steam. Again, heat has to be expended in superheating this steam, the ratio of the heat given per lb. to superheated and to saturated steam at the same pressure being $\frac{H + Kt}{H}$, where t is the degree of superheat, K the mean specific heat of superheated steam within the limits of superheating, and H the total heat of saturated steam at the given pressure. So that finally, calculating the work done per heat-unit with saturated and with superheated steam, we find that the advantage to be gained by superheating, from this point of view, is very slight indeed. The great economy which is obtained in practice must therefore be looked for in some other direction.

It is now generally understood that the main use of superheating is to diminish initial condensation, with its concomitant evils—increased transference of heat from steam to metal, increased rejection of heat to the condenser, and increased leakage past steam and exhaust valves.

In the steam turbine, working as it generally does without any large fluctuation of temperature in the cylinders, there should be little initial condensation, and here we find the economy due to superheating in the fact that this tends to reduce the liquefaction which of necessity takes place in the cylinders, due to the performance of work by the steam. The viscous resistances to rotation, due largely to the presence of a film of water between the fixed and moving vanes, are hereby lessened. The resistance to rotation of the rotor discs, due to the friction of the medium in which they rotate, is also greatly reduced as the density of the steam is diminished by superheating.

In the case of a turbine of the De Laval type, too, when wet steam is being used, the small apertures in the nozzles are apt to be intermittently choked up by the accumulation of water which occurs, this militating against steady running.

As to the best type of superheater to use, much depends upon circumstances as to whether the independently fired superheater, or the superheater consisting of a nest of tubes fixed in the boiler flues, and using what would otherwise be waste heat from the furnaces, is to be advised.

The latter type has the advantage of cheapness, takes up less room than the former type, and is generally more economical in working; experiments made by Professor W. H. Watkinson, in connection with the different types of superheaters constructed by Messrs. Mechan & Sons, Ltd. of Glasgow, under his supervision, showing that with an independently fired superheater the percentage saving in coal is about 5 per cent. less than the saving in steam, while with the flue-fired type the saving in coal is greater than that of steam.

In spite of this fact the independent superheater is generally to be recommended, in virtue of its flexibility and of the ease with which the degree of superheat can be maintained constant or can be varied to suit varied conditions of working. This is especially the case with a superheater fired by a furnace of the gas producer type, the degree of superheat in that case being almost instantaneously regulated by regulating the admission of steam to the blower which supplies air to the furnace.

Another great advantage of this type of superheater is that the necessity for

flooding the tubes while raising steam is obviated, this leading to greater durability and giving a much longer life to the superheater.

The Tariff Commission Report.

WITHOUT the least exaggeration it may be said that no document of greater importance to the engineering industry of the United Kingdom than the recent Report of the Tariff Commission has been placed before the British public within the last quarter of a century. Attempts have been made in some quarters to cast discredit upon the Commission by describing it as a purely party organisation, and in other quarters the suggestion has been made that its promoters have committed a sin almost approaching sacrilege in presuming to institute independent inquiry, instead of waiting patiently for the appointment of a Royal Commission.

With regard to the first point, all reasonable people must admit that the Tariff Commission is in no way a political body, for the names of its members are a sufficient guarantee that all shades of political opinion are adequately represented.

So far as concerns the second point, while admitting the invaluable work done by many Royal Commissions, the deliberations and the procedure of such bodies are unnecessarily protracted, the publication of their Reports is often delayed far beyond all reasonable bounds, and the recommendations made are frequently ignored by the Government of the day. Moreover, in the constitution of a Royal Commission we generally find the names of too many professional politicians, who have no real qualification for dealing with the subjects for inquiry.

Even though it has not been established under the auspices of Parliament, we are convinced that the Tariff Commission commands the respect and confidence of all reasonable men, and especially of those engaged in industrial pursuits. It was appointed in the first place to obtain hard facts, and these could be collected only by the consent, approval, and co-operation of all the industries in the United Kingdom. The Commission has wisely departed from the slow-moving methods generally adopted, and, in addition to the examination of numerous witnesses, has sent out inquiry forms to all makers of iron and steel, as well as to merchants and manufacturers engaged in the trade.

Consisting almost exclusively of great leaders of industry, the appeal for information made by the Commission has met with a wonderful response, and the thoroughly representative character of the evidence furnished is shown by the fact that the firms answering the inquiries employ more than 87 per cent. of the total number of persons engaged in the trades involved. But the Commission is not only qualified to collect information; it is also qualified to consider it, and to publish the results for the benefit and guidance of the country. In the Report to which attention is now directed we have the first fruits of the labours conducted by the thoroughly competent body appointed to examine the fiscal proposals submitted to the Empire by Mr. Chamberlain. It is already well known that the United Kingdom has long ago fallen to the third place among nations producing pig-iron, and that, whatever be the test applied, the pig-iron industry is proved to be almost stationary. The same disastrous development is evidenced in the case of steel, for we are not only relegated to the third place among the nations, but, while the demand for steel is rapidly increasing in all parts of the world, we remain stationary although the United States and Germany are rapidly progressing. It is true that there has been an increase in the home consumption of steel, but the diminution of exports and the corresponding increase of imports prove that foreign and not British manufacturers have benefited by the improved condition of the market. With regard to the Colonies, our trade is certainly increasing, but with foreign countries it is growing less and less, and foreign manufacturers are making larger inroads into Colonial markets. Examination of the voluminous records presented

in the Tariff Report show a lamentable decline of the British iron and steel industries, and the experience of manufacturers points clearly to the severity and unfairness of foreign competition, rapid substitution of foreign for British-made materials, and the loss of foreign markets, chiefly through the operation of hostile tariffs. Careful perusal of the evidence makes it abundantly clear that the era of foreign competition is merely beginning, and that energetic action is necessary if the iron and steel industries are to be maintained. The practice known as "dumping," conducted on such lines as to be profitable to foreign manufacturers, has already caused serious loss of employment and diminished profits, and has utterly unhinged the markets of this country. Practically all who are engaged in the manufacture and sale of British iron and steel concur in the belief that it is absolutely essential to curtail the advantages now enjoyed by our foreign rivals in the home market, and that this can only be done by the adoption of a protective tariff. We are glad to observe, however, a general consensus of opinion that whatever measures are finally adopted should be carefully calculated, and applied in a thoroughly business-like manner. The British system of free imports is an absolute anachronism in the present day, which must be abolished. It is satisfactory to find that after mature deliberation the Tariff Commission has arrived at the sound conclusion that the British fiscal system should be revised, so as to check the practice of dumping, to maintain our export trade, to develop our Colonial markets, and to increase the employment of the working classes.

The iron and steel trades are already free from the pernicious and antiquated doctrine of so-called "Free Trade," and we believe the splendid work of the Tariff Commission will do much to awaken the nation to a sense of past errors, and to stimulate the resolution to avoid them in the future.

New Irrigation Works for Egypt.

By the persistent and unassuming work of twenty years the Public Works Department of Egypt prepared the way for the execution of the Nile Reservoir Works, which have been fully described in previous issues of THE ENGINEERING REVIEW and in the technical and popular press of the entire world. Three great achievements stand forth as striking examples of what has already been accomplished: the rehabilitated Delta Barrage, the Aswan Dam and the Asyût Barrage. By the first of these, as Sir Hanbury Brown has lately told the British Association, the cotton crop of the Delta has been doubled in value from £7,500,000 to £15,000,000, and the cultivated area has been increased by 1,000,000 acres, which represents an addition of fully £30,000,000 to the national wealth. By means of the second, as Lord Cromer has reported, the value of land in Middle Egypt has been raised by at least £5,100,000, and even this is not half the eventual result that may be expected in three years more. As for the third, Sir William Garstin has officially stated that its cost was actually repaid by the results of the first year's working.

These convincing proofs of the wonderful efficacy of irrigation works have done much to clear the way for further enterprise, and Egypt now stands on the brink of developments that, when finally effected, will dwarf into comparative insignificance all that has been accomplished in the past. Those who desire full particulars of the projects to which we now refer will find them in a recently published Blue-book, consisting mainly of the Report upon the Basin of the Upper Nile, by Sir William Garstin, K.C.M.G., the indefatigable chief of the Public Works Department.

We must content ourselves in the present article with a mere outline of the vast undertakings foreshadowed in the Report. Dealing first with Egypt proper, we find it is proposed to raise the Aswan Dam to its full height, thus doubling the capacity of the reservoir, and paving the way for

the adoption of perennial irrigation on 750,000 acres of land, and for the irrigation of 100,000 acres by means of pumps. The cost of raising the dam is estimated at £500,000, while the conversion works, including two barrages between Aswan and Asyût, will involve an ultimate expenditure of about £5,000,000. The return for this outlay in the form of land tax, railway and Custom receipts will be little short of £500,000 per annum, while the value of the lands will be increased by more than £25,000,000. In Lower Egypt it is proposed to remodel the Rosetta and Damietta branches of the river, treating the Damietta branch simply as a canal, and making the Rosetta branch capable of carrying the full flood of the Nile so as to afford adequate protection against the disastrous effects that are now threatened on the occurrence of the next dangerously high flood. This project is estimated to cost £900,000, and, bearing in mind the experience of past years, we must say that it will be money well spent. Even after the raising of the Aswan Dam, more water will still be required, and Sir William Garstin proposes to obtain additional supplies by cutting a new channel for that portion of the White Nile which passes through the swampy regions above Fashoda. The formation of such a channel, at an estimated cost of £5,500,000, would obviate the enormous waste of water now taking place to the extent of more than 50,000,000 cub. m. per day. By bringing down to Khartoum the bulk of the water wasted in the marsh region, the summer discharge of the river would be increased by 50 per cent. This, Sir William Garstin says, would suffice for present requirements. But he goes a step further, and proposes that, after the construction of the new channel, the regulation of the Great Lakes should be taken in hand. The only works necessary for this purpose are two regulating weirs at the respective outlets of Lakes Victoria and Albert, and the cost of which would not exceed £1,000,000 each. By their completion the almost illimitable resources of these inland seas would be placed at the disposal of the Irrigation Service, and, taking into account the other means of regulation that would then exist, the whole of the White Nile, from its source to the sea, would be as completely under control as the delivery mains of any waterworks undertaking. The projected works on the Upper Nile would make it possible to bring under cultivation in Lower Egypt an additional area of 800,000 acres, capable of yielding an extra revenue of about £1,000,000 per year, and of adding to the national wealth an amount of nearly £25,000,000. But, beyond this, the increased water supply would be available for the development of those parts of the Soudan situated along the Nile Valley, and representing an area of at least 200,000 acres. In respect of these we may safely reckon a return of £100,000 in land tax, and £6,000,000 in the increased value of the land.

So far as we have gone, the approximate cost of the works enumerated is £13,900,000, while the promised return is £56,000,000, in addition to a yearly revenue equal to more than 10 per cent. on the capital expenditure.

The Report, however, deals also with the case of the Eastern Soudan, and foreshadows extensive projects for the control of the Blue Nile, and other rivers in that region. At present, only four schemes are recommended for consideration, for the complete development of the Soudan is a stupendous task, that will require almost unlimited expenditure and continuous work for generations to come. The schemes to which we refer are, the construction of a reservoir at Rosaires, a barrage near Wad Medani, and an irrigation system in the Ghezireh district, all on the Blue Nile, and a scheme for the improvement of the Gash River. These four projects are estimated to cost £5,500,000 in all, and the return in revenue is estimated at £400,000 per annum, in addition to the augmented value of the lands affected.

In connection with all the schemes mentioned, considerable sums will have to be spent on drainage and other incidental works, and until further studies have been made, it will be impossible to speak definitely as to the actual cost of the proposed undertakings. In the mean-

time, the figures quoted are sufficiently near the mark for the general guidance of our readers, and serve to indicate the extensive character of the recommendations now placed before the Egyptian Government.

Before closing this brief review, we ought to state that, in his despatch accompanying the Report, Lord Cromer expresses the opinion that the programme prepared by Sir William Garstin may safely be adopted, in the sense that the aim of the Egyptian Government should be to work gradually up to the execution of the schemes, dealing first with those of urgent character, and leaving others for future consideration. Lord Cromer considers, further, that a sum of probably £3,000,000 should be spent in placing the Egyptian railways in thorough order, and expresses the hope that the Suakim-Berber Railway, the total cost of which will be about £1,750.000, may be finished by the spring of 1906.

All who are interested in the good work that England is doing in the countries under her control, will find this Report worthy of careful study, and, after perusal, will agree with us that Sir William Garstin has fully earned the gratitude of Egypt and his fellow-countrymen, by the ability with which he has dealt with the great and difficult problems discussed in its pages.

Revised Fire Rules.

THE Fire Offices' Committee have just issued a revised set of rules for electro motors in use in textile and corn mills and other buildings, where motors are exposed to dust and flyings. The essential difference between the new rules and those which they supersede, appears to be that the former allow unprotected ventilating openings in the metal covers of induction motors, provided the superficial area of each opening does not exceed ¼ in. and provided the openings are ¼ in. apart. The following are the new rules :—

1. Motors when not in an engine-room or in a separate compartment expressly set apart for their use and built of or lined with incombustible material must be completely enclosed in an efficient metal case forming part of the designed construction thereof.

Ventilation by direct communication with the outer air or by openings in the vertical portion of the metal case protected by two thicknesses of approved wire gauze is allowed.

Induction motors may have unprotected ventilation openings in their metal cases, the superficial area of each opening not exceeding ¼ in. and the openings being at least ¼ inch apart. Slip rings and brushes or any other sliding contacts must be completely enclosed in metal cases.

Inspection holes fitted with plate glass are allowed.

2. No unprotected woodwork or combustible material must be within 18 ins. of any motor, and wood flooring beneath any motor must be protected by a sheet of metal.

3. The motor pulley (or other mechanical device for transmitting power from the motor) must be external to the metal case enclosing the motor. Only the shaft and the connecting conductors may be carried through into the metal case or through the wall of the compartment. No belts. ropes, or other corresponding gear may be so carried.

NOTE.—Holes in the case to admit connecting conductors must have proper bushings, and exposed terminals must have proper protecting caps fitted, to prevent short circuiting. Each connecting conductor must be provided with a proper switch and proper cut-out.

4. Dynamos must be treated as motors.

5. Resistances and starting transformers must be similarly situated and must be enclosed as required for motors.

6. All metal cases, tubes, etc., must be efficiently connected to earth.

7. Motors must not be supplied with current from dynamos or conductors having an earth return.

Coke Ovens and their History.*

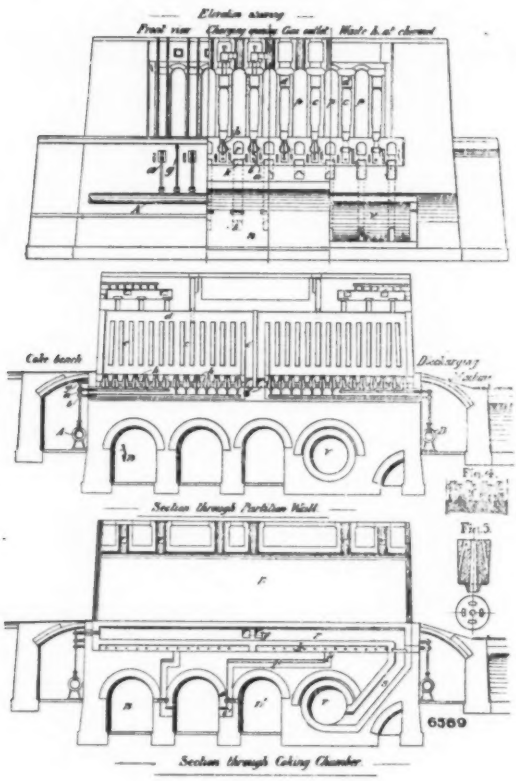
By PAUL J. MAULMANN, M.A.

THE author, in a most interesting and valuable paper, reviews the principal system of coke ovens, from the earliest Beehive type down to the most recent by-product recovery oven, and concludes with a consideration of the value and utility of the by-products obtained. The more recent types of coke oven consist essentially of long, horizontal, narrow-arched coking chambers, with doors at each end, the chambers being heated by flues outside, arranged either horizontally or vertically. The exclusion of atmospheric air is an essential feature of these ovens, and in contradistinction to the beehive type the coal to be coked presents a narrow and high formation to the heat, instead of a large heap. In the one case a short coking period is obtained, and in the other one of longer duration; on the duration of the coking period depends, of course, the output in a given time. Preheating the air which is introduced into the heating flues for the combustion of the gases is adopted in some ovens, when a regenerator is made use of for this purpose. The ovens are charged through openings in the roof of the coking chambers, but when stamped coal is to be coked the oven is charged by the charging ram. The dimensions of the ovens generally adopted are approximately as follows:—

	Length.	Width.	Height.
1. Simon-Carves ...	28 ft.	20 in.	6 ft. 6 in.
2. Semet-Solvay ...	30 ft.	16½ in.	5 ft. 6 in.
3. Coppée	30-33 ft.	16-24 in.	4-4½ ft.
4. Otto Hoffmann	33 ft.	20 in.	5 ft. 3 in.
5. Otto Hilgenstock	33 ft.	20 in.	5 ft. 11 in.
6. Huesner.....	29½ ft.	22½ in.	5 ft. 8 in.
7. Franz Brunck ...	3 ft.	20 in.	5½ ft.
8. Koppers.....	30 ft.	18-20 in.	5 ft. 6 in.
9. Von Bauer.....	26-39 ft.	21½ in.	7 ft.
10. Collins	30 ft.	18-20 in.	5-6 ft.
11. Poetter	33½ ft.	20½ in.	6½ ft.

The width of the ovens is the most important factor as regards the duration of the coking period. The output per 24 hours varies from 2½ to 4½ tons of coke per oven, the amount of output depending to some extent on the quality of the coal to be coked. Detailed and illustrated particulars of the above-mentioned types are given, of which the last on the list — viz. the Poetter — may be selected for detailed description here. In this type the gas returning from the condensing plant enters the oven at both ends into channels *A B* independent of each other, and which are in connection with the gas-distributing flues. As the latter are divided by a central wall, only one-quarter of the partition walls of the coking chamber, or one-half of each partition wall, is heated. This arrangement ensures an equal pressure of gas and consequently a uniform distribution round the coking chamber *pp*, as all burners *k* of vertical flues *c* deliver the gas jet *k* at the same pressure. The gas is distributed by fire-brick burners, which are superior to iron, as they do not become clogged by tar. Each flue *a*, *b* serves several burners, and to ensure a uniform distribution of the gas for all burners, the two flues are arranged one over the other. Each verticle flue *c* is heated by a burner, by which means the partition wall is uniformly heated. The combustion air is pressed by a fan into the flue *n*, and ascends through two side flues *i* into a channel under the heating flue *k*, and enters in a heated state into a space near the burners; it here passes through slits in the fire-brick burners into the heating flues. The constructor of this oven claims that its high efficiency is obtained by the regular distribution of heating gas, based on the introduction of the gas at both oven heads. The period of coking is considerably shortened (20 to 26 hours) by the high temperature obtained by his plan of heating the partition wall by flaming gas, giving an output of coke up to 78 per cent., subject to the quality of the coal. It is also stated that the uniform heat created by this construction in the coking chamber has favourable results as regards output and quality of coke and by-products, so that the working of these ovens ensures a most successful financial result. Their erection is inexpensive, and their simple construction makes them very durable, obviating the necessity of repairs for a very long time. The heating of the coking chamber requires about 50 per cent. to 55 per cent. of the gas developed by the coking process, so that 45 per cent. to 50 per cent. remain available for driving gas engines or for heating purposes. The regular temperature in these ovens also results in a gas production of the most suitable quality for the recovery of by-products. Poetter's claims for his ovens are:—(1) That the use of especially moulded fire-bricks in building up the partition wall ensures freedom from repairs, and that consequently all joints are perfectly tight, and leakage of gas and air is excluded. (2) The partitioning of the wall, and the use of a set of flues for a limited number of burners, secures a regular distribution of gas, and perfectly uniform temperature, giving an output of 5½ tons of coke in 24 hrs. per oven. (3) That the burners are of a material not liable to be clogged by tar, and therefore never fail to supply gas. (4) That access to all flues is possible, and easily obtained. (5) That the coking process is uninterrupted and regular, ensuring a silver-grey, uniformly carbonised coke for blast furnaces. (6) that they secure a large output of coke and by-products, leaving 45 per cent. to 50 per cent. of gas for

* Lecture before the Cleveland Institution of Engineers, Middlesbrough.



THE POETTER COKE OVEN.

motor and heating purposes. (7) That the initial outlay is low. The author, in concluding his paper, draws attention to the fact that in the design of coke ovens a cheap victory has fallen to the foreign engineer, due entirely to the mental lethargy of his British compeer, who dislikes innovations. It appears that from 1620, the date of the first coke-oven patent ever granted in England, practically up to 1875, almost all patents for coke ovens fell to the lot of Britishers or such as had been the greater part of their lives in this country. From 1875 to the present day, practically every patent for up-to-date, modern by-product recovery coke ovens has been granted to foreigners. The inference is obvious.

The Advantages of Superheating or Steam Jacketing as applied to the Steam Turbine.

By A. H. GIBSON, B.Sc., Wh.Exh.

CONSIDERING the steam turbine as a heat engine—that is, simply as a machine for turning the greatest possible percentage of heat in a given quantity of steam into useful work—and examining its design with that end in view, we find several points in which its design proceeds along different lines from that of an ordinary reciprocating steam engine—many others where their designs follow parallel lines.

One reason for this divergence in design arises from the fact that, whereas in the reciprocating engine steam is alternately admitted to, expanded in, and exhausted from the cylinder, the whole cylinder being at one instant in contact with high-temperature steam, and at the next instant with steam at a much lower temperature, in the steam turbine, steam generally passes in a steady stream through the turbine cylinder, expanding and falling in temperature on its way, and any particular part of this cylinder is always in contact with steam at the same temperature. The walls of the turbine cylinder are therefore not subject to those cyclic variations of temperature, which occur in the walls of the cylinder of a reciprocating engine.

In a previous issue of the ENGINEERING REVIEW (Vol. 10, No. 2), it was shown how this cyclic variation in temperature led to cylinder condensation, with its concomitant evils—increased transmission of heat from steam to metal at each stroke of the engine, to increased leakage past admission and exhaust valves, and to rejection of an undue proportion of heat to the condenser. It was also shown that if the steam could—by means of steam jacketing the cylinder, or by initial superheating—be kept dry throughout the stroke, these bad effects could be minimised very considerably.

Now in any heat engine, whether reciprocating or turbine, which uses steam as the medium for carrying the heat used, the work done must be done at the expense of part of the heat contained in the steam, and if the steam is supplied initially saturated, the abstraction of this heat must of necessity lead to liquefaction in the cylinder. If it is desired to prevent this liquefaction, extra heat must be given to the steam, either before its entrance into the cylinder or during its passage through the cylinder, and the article in question showed how this might be done by a system of steam jackets in the case of a reciprocating engine.

But in a steam turbine it is equally important, though for different reasons, to prevent this liquefaction, for a source of loss now comes in which is negligable in the case of a reciprocating engine—namely, the loss due to friction of the steam on the walls of the steam passages, and on the moving surface of the turbine discs. Experiments show that these frictional losses are of very great importance, especially in turbines of the de Laval or Curtis type, in which the relative velocity of the steam jets and of the rotating vanes is very great.

It is found that these frictional losses are lessened as the density of the steam is diminished, and that with dry steam they are considerably less than with supersaturated steam.

In turbines of the Parsons type, too, in which the clearance between the stationary and rotating vanes is made extremely small, in order to prevent excessive leakage of steam, if wet steam is being used, a film of water is deposited on all the metal surfaces, and this film causes a large increase in viscous resistance between the stationary and rotating vanes.

Again, in any type of turbine, if wet steam—steam containing suspended

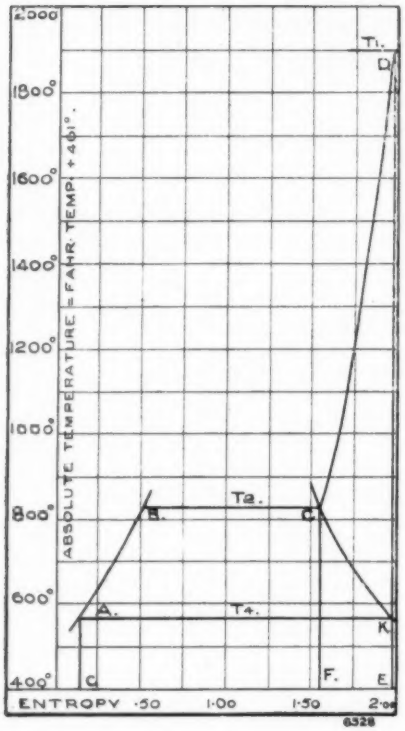


FIG. 1.

particles of moisture — be used, this moisture has another deleterious effect.

The steam is passed in a jet or series of jets, moving with considerable velocity, into a series of curved vanes, and is forced to follow a curved path, and so change the direction of its motion. Centrifugal action is of course set up, and the particles of moisture being denser than the surrounding steam, will be deposited on the outer boundary of the curved surface.

If the steam be initially wet, this will take place on the first row of vanes or blades, and as the viscous friction between this film of water and the metal surface of the vane is very great—much greater than that between steam and metal—the velocity with which this water will leave the vanes is much less than that of the steam itself.

The effect of these comparatively slow moving particles of water in the jet of high-velocity steam will be to make its velocity, on leaving the first and all successive rows of blades and vanes, less than that calculated and to set up eddy currents in the steam itself. Evidently, too, this effect will be exaggerated in each successive row of vanes; and, as the economical working of a turbine depends on the angles of vanes and blades being suited to certain velocities of the steam at different points in its passage through the turbine, this will directly lead to uneconomical working. The later in the cycle liquefaction takes place, the less will this bad effect become.

For these three reasons, then, it is highly important that in a steam turbine, as well as in a reciprocating engine, liquefaction should be as far as possible prevented, and that the steam should be kept dry from the stop valve until it enters the condenser.

There are four ways in which the extra heat necessary for the steam to be kept dry may be given to the steam, and it is proposed to examine these in detail, and to determine which method is most advantageous for any particular type of turbine.

The four methods are—

1. Initial superheating.
2. Initial superheating, with reheater between cylinders or stages of turbine.
3. Steam jacketing the turbine casing.
4. Combination of superheating and steam jacketing.

Initial Superheating.

In order to see to what temperature the steam must be superheated, in order that no liquefaction may take place in the turbine, the temperature-entropy-$\theta - \phi$ diagram Fig. 1 is drawn. Here steam at an absolute temperature $\tau_2{}^\circ$ (absolute temperature = temperature Fahr. + 461 degs.) is superheated up to a temperature τ_1, and expanded adiabatically down to a temperature τ_4. In Fig. 1, AB is the water entropy line, drawn under the assumption that the entropy of water at 493 degs. (32 degs. Fahr.)

is zero, the entropy at any temperature $\tau°$ absolute being obtained from the equation $\phi = \int_{493}^{\tau} \frac{d\tau}{\tau}$ so that $\theta_2 = \log_e \tau_2 - \log_e 493$.

$C\,K$ is the entropy line for saturated steam, the entropy of the steam at any temperature being equal to that of water at that temperature $+ \frac{L}{\tau}$, L being latent heat of steam at a temperature $\tau°$. Since $L = 1437 + 0{\cdot}7\tau$, the entropy of saturated steam at a temperature $\tau°$ is given by the equation $\theta = \log_e \tau - \log_e 493 + \frac{1437}{\tau} + {\cdot}7$.

$C\,D$ is the entropy line for superheated steam, being calculated on the assumption (which is probably very approximately true) that the specific heat of superheated steam at all temperatures within our range is $0{\cdot}5$.

Thus, if steam at $\tau_2°$ is superheated up to $\tau_1°$, the increase in entropy is ${\cdot}5 \int_{\tau_2}^{\tau_1} \frac{d\tau}{\tau} = {\cdot}5\ (\log_e \tau_1 - \log_e \tau_2)$.

If now τ_1 be so chosen, that the vertical line $D\,K$ (the adiabatic expansion line) cuts the saturated steam line at its intersection with the temperature line $A\,K$, which corresponds to the temperature of exhaust, the steam will just become saturated at exhaust, and τ_1 will give the necessary temperature of superheat. To calculate τ_1 we note that the entropy of the steam after superheating from τ_2 to τ_1 is equal to the entropy of saturated steam at a temperature τ_4. So that we have :—

$${\cdot}5\ (\log_e \tau_1 - \log_e \tau_2) + \log_e \tau_2 - \log_e 493 + \frac{1437}{\tau_2} + {\cdot}7 = \log_e \tau_4 - \log_e 493 + \frac{1437}{\tau_4} + {\cdot}7,$$

or $${\cdot}5\ (\log_e \tau_1 + \log_e \tau_2) + \frac{1437}{\tau_2} - \frac{1437}{\tau_4} - \log_e \tau_4 = O.$$

Fig. 1 is drawn for a turbine working between the pressures 165 lbs. absolute (150 lbs. gauge) and 1 lb. absolute. The temperature τ_1 under these conditions is 1942 degs. absolute, or 1480 degs. Fahr., so that in order that the steam may be kept dry in its passage through the turbine, it must be superheated up to 1480 degs. Fahr. With any less degree of superheat the steam would become wet before falling to exhaust temperature.

This temperature is quite inadmissible in a turbine of the Parsons type which admits steam at initial pressure and temperature directly to its moving parts, both on account of the very serious effects of unequal expansion of the turbine casing and rotor at such high temperatures, and also because of the weakening effect of such temperatures on the materials of construction. So that in the case of a Parsons turbine or of such a turbine as the Curtis or Rateau using separate expansion chambers where the steam is passed directly from one chamber to the next without reheating, it is impossible to give enough heat to the steam by initial superheating to totally prevent liquefaction. Of course any degree of superheat will prevent liquefaction to a certain extent, and will to that extent tend to diminish the viscous resistances.

In a turbine of the de Laval type, however, in which steam is expanded by diverging nozzles down to say 1 lb. absolute pressure before entering the turbine proper, the steam will—following the adiabatic expansion line DK—just become saturated on entering the turbine, and will then have the temperature corresponding to saturated steam at that pressure, so that in this case—provided the superheater can be arranged to stand the high temperature—this would appear to be the most suitable method of preventing liquefaction.

The second method is by ***Superheating*** and ***Reheating***.

Where the steam is used in two or more distinct stages, as in the case of the Westinghouse-Parsons tandem type, or where, as in the case of a turbine of the Reidler-Stumpf or Curtis type, the steam may be led through a reheater, on its way from one chamber to the next, initial superheating, with intermediate reheater between the cylinders, is more likely to give satisfactory results.

Fig. 2 shows the temperature entropy diagram for a cycle in which steam at 165 lbs. absolute pressure is superheated to a temperature τ_1 and expanded down

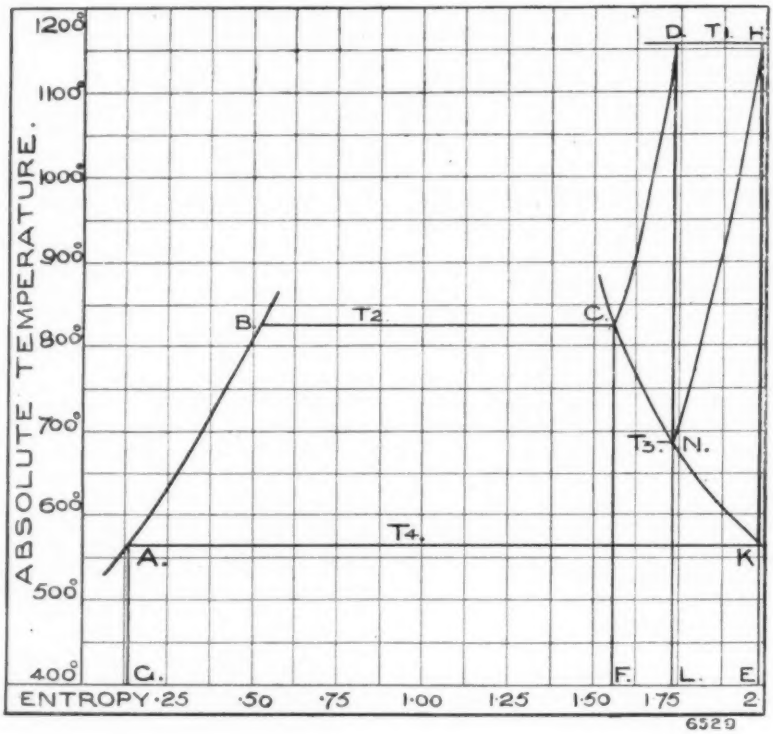


FIG. 2.

to a temperature τ_3 and the corresponding pressure of saturation in the first or high-pressure cylinder of a turbine. It is then reheated to the same temperature τ_1 its pressure remaining constant, and is expanded in the low-pressure cylinder down to 1 lb. absolute pressure.

As in Fig. 1 CD is the $\theta\phi$ line for superheated steam; DN is the expansion line for this steam cutting the saturated steam line CK at N. NH is the entropy line for the reheated steam, and HK its expansion line. If the degree of superheat be so chosen that HK cuts the saturated steam line CK at K, on the temperature line, corresponding to the exhaust pressure (1 lb.), the steam will remain dry throughout its passage through the turbine.

In this particular case, the necessary temperature of superheat and of reheating would be 696 degs. Fahr., and though this degree of superheat is quite practicable, yet with turbines using steam at much higher pressures, the necessary temperature of superheating would be too high, unless more than two stages of expansion were used. Up to, say, 150 lbs. boiler pressure, however, this is probably the most effective method of preventing liquefaction, either for turbines of the diverging nozzle type, or for two-stage turbines of the Parsons type, though in the latter case, difficulties caused through unequal expansion of the working parts would have to be faced.

This system, too, while being less efficient from a thermodynamical standpoint than the previous system of super-

heating without reheating, since part of the heat is taken in at a lower temperature, is yet more efficient than the method of steam jacketing, for the same reason.

While this system necessitates the installation of a superheating plant, either separately fired or as part of the boiler, it has the advantage over the system of steam jackets, that a slightly simpler construction of turbine casing is admissible. On the other hand, in order that the steam may be reheated between the high-pressure and low-pressure cylinders, a further complication is introduced.

The third method of preventing liquefaction is by steam jacketing the whole or part of the turbine casing; and, as the efficiency of a steam jacket depends very largely on the temperature gradient between the two faces of the jacket, it is advisable in every case to use jacket steam at as high a temperature as possible—straight from the boiler, in fact.

Jacketing.

Consider the case of a turbine, as before using steam between the pressures 165 lbs. and 1 lb. absolute, and developing 1 h.p. for every 15 lbs. of steam per hour. Fig. 3 is the temperature entropy diagram for this cycle of operations, assuming that sufficient heat is applied by a steam jacket around the turbine casing, to keep the steam perfectly dry. The temperature lines *B C* and *A K* correspond to the pressures 165 lbs. and 1 lb., and *C K* is the entropy line for saturated steam. Then the area *C F E K* represents the heat which must be given to each pound of steam by the jacket, during its passage through the turbine. In this particular case, this amount of heat is 285 B.Th.U.

Taking as a specific case, that of a 500-h.p. turbine, passing 7,500 lbs. of steam per hour, or 125 lbs. per minute, this means that the jacket must give $125 \times 285 = 35{,}625$ B.Th.U. per minute.

Assuming that the thickness of the turbine casing is 1 inch, and taking Pèclet's results as being correct for the heat conductivity of cast iron, we find that for each degree Fahr., of difference in temperature between the two sides of the casing, each square foot of the surface will pass 3·87 B.Th.U. per minute. The product of the difference of temperature and of the surface area of the jacket in square feet must therefore $= \frac{35{,}625}{3{\cdot}87} = 9{,}200$.

In a turbine of the Parsons type, the fall in pressure, and therefore in temperature, of the steam is gradual from end to end of the turbine, and the mean temperature of the steam working between pressures 165 lbs. and 1 lb. will be approximately 220 degs. Fahr.; so that assuming steam at boiler pressure and temperature 366 degs. Fahr. to be used in the jacket, the mean difference of temperature would be 146 degs., and a jacket area of $\frac{9{,}200}{146} =$ 63 sq. ft. would be necessary for efficient jacketing.

Since a turbine of this type, to give 500 h.p., would be at least 3 ft. 6 ins. in diameter and 9 ft. long, evidently it would be quite practicable to arrange for this amount of jacket surface.

Evidently the jacket surface surrounding the second half of the turbine, where the steam temperature is low, will be the more efficient, and it is likely that, during the passage of the steam through the first few rings of blades and vanes, the difference in temperature will not be sufficient to entirely prevent all liquefaction at this point. As shown previously, moisture deposited on the first rings of blades has a deleterious effect on the remainder of the incoming steam, until it is entirely re-evaporated, so that it is important that this initial liquefaction should be prevented. This might be done by initially superheating the steam to a slight extent, and this combination of slight initial superheat, with steam at boiler pressure in the jacket, would appear to be the ideal system so far as economy in steam consumption is concerned.

Again, the use of the steam jacket would appear to be particularly suitable for a steam turbine, since the steam in its passage through the turbine, comes so intimately in contact with the heated jacket surfaces, and since its velocity over those surfaces is very great, both conditions tending to rapid transference of heat from jacket surface to steam. Also the

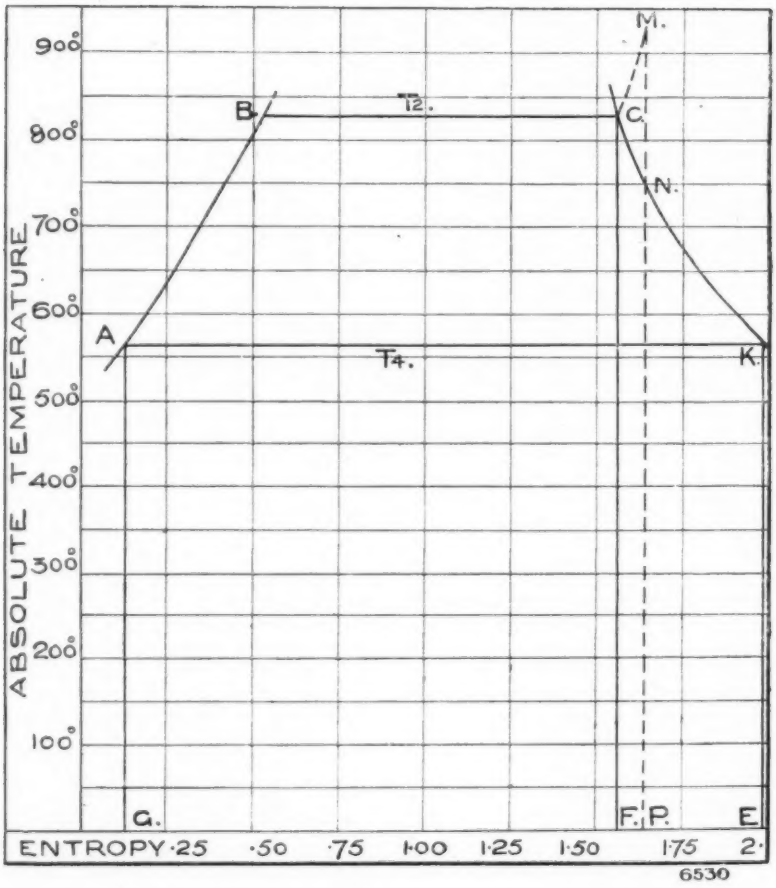


FIG. 3.

range of temperature through the length of the turbine casing is reduced by the use of a steam jacket, and the difficulties due to unequal expansion are thereby minimised. In this respect the steam jacket has a great advantage over the superheater, especially for a machine of the Parsons type.

Jacketing is, however, generally quite unsuitable for a turbine of the diverging nozzle type, except in combination with a system of superheating, as owing to the high velocity of the steam through the nozzles, and to the small surface area of those nozzles, it would be impossible to give enough heat to the steam in its passage through the nozzles to prevent the liquefaction which necessarily takes place there owing to the conversion of heat energy into velocity energy. The steam is therefore very wet on entering the first ring of blades.

Again, in a turbine of this type, owing to the small number of rings of blades and vanes, the area of surface of the casing is in general so small, that the difference in

temperature between the jacket steam and the working steam would have to be excessive in order to give the required amount of heat to thoroughly dry the steam between one chamber and the next. It still remains, then, to consider the remaining system.

Combined Jacketing and Superheating.

In this system a moderate amount of initial superheat given to the steam will suffice to keep it dry until its temperature has fallen with its pressure enough to make the jacket surfaces highly efficient, the jacket being supplied with steam at boiler pressure and temperature.

Suppose, for example, a turbine of the Parsons type working between 165 lbs. and 1 lb. pressure, with the steam initially superheated through 100 degs. Fahr. The dotted lines *C M N P*, Fig. 3, show the effect of this superheating, *C M* being the entropy line for the superheated steam. Where the adiabatic expansion line *M N* cuts the saturated steam line *C K*, we get the temperature at which the steam just becomes saturated. This temperature in the given case is 740 degs. absolute, or 280 degs. Fahr., corresponding to a pressure of 50 lbs. absolute. From this point down to the exhaust, the mean temperature of the steam is about 180 degs. Fahr.

Now, in order to keep the steam dry from this point down to the exhaust, an amount of heat, represented by the area *N P E K*, must be supplied by the jacket. This amount of heat is 220 B.T.U. per pound of steam passing through the turbine.

Taking the same turbine as before, passing 125 lbs. of steam per minute, the heat given by the jacket per minute is 125 by 220 = 27,500 B.Th.U. The mean difference in temperature between the jacket steam and the working steam is 156 degs. Fahr., so that the area of the jacket surfaces must be $\frac{27{,}500}{156 \times 3{\cdot}87} = 45$ sq. ft. In a turbine of the Parsons type, this area would be available for jacketing, as, assuming the diameter of the low-pressure cylinder of the turbine to be 4 ft., it would only necessitate jacketing the last 4 ft. of the turbine casing.

It is worthy of notice, that the method which is adopted in governing a turbine of the Parsons type, namely, that of admitting steam in gusts at intervals, makes the question of jacketing or superheating of still greater importance.

In this case we get a fluctuation of pressure and therefore of temperature at each part of the turbine, corresponding to each admission of the steam, this fluctuation of temperature introducing all the evils due to initial condensation which are absent in the case of a turbine such as the Curtis or de Laval, which govern by cutting out one or more nozzles completely.

It would appear, then, that in order to prevent liquefaction, the best system to use in the case of the one-stage de Laval type, is that of a high degree of initial superheat—with a turbine of the multiple-stage Curtis-Riedler-Stumpf or Westinghouse-Parsons type, initial superheating to a moderately high degree, with reheating between the stages of expansion, is preferable—while with a turbine of the single-chamber Parsons type, steam jacketing without, or preferably with low initial superheat, will give the best results.

In this Paper, the author has confined himself to general theoretical considerations of economy.

In practice, each case must be considered on its own merits; other considerations of first cost—depreciation, upkeep, etc.—sometimes making the disadvantages of one system more than outweigh its obvious advantages. Still, a consideration of the principles briefly laid down here, may indicate the lines along which improvement in design and in economy should be sought.

The Fatigue of Metals.

By ARTHUR N. KEMP.

ONE of the first to look thoroughly and systematically into the question of the fatigue of metals was Herr Wohler, who undertook experiments between 1859 and 1870, for the Prussian Ministry of Commerce, in order to determine the capability of metals to withstand repeated and alternating straining actions.

In 1864, Sir William Fairbairn read a paper before the Royal Society, giving the results of experiments, carried out by him, on the effects of repetitions of stress on a wrought-iron girder, but his investigations, though valuable, were very limited and are not worth further consideration here, except to mention that his experiments were quite in accordance with Wohler's contemporaneous work.

Wohler set himself a stupendous task in carrying out his tests, some of them—No. 9 in accompanying table being an instance—occupying considerably over three years, the alternating stress in this case being applied 144 times a minute without cessation. The results of Wohler's researches published in 1871, in "Engineering" Vol. XI., show that the strength of a piece of material, as found by ordinary direct testing and calculated on the maximum intensity of stress, is not a sure guide when the material is to be subjected to a constantly varying stress, or even the complete reversal in the direction of stress. He showed that the number of repetitions of stress that a material could safely stand varied to a remarkable degree with the intensity of the stress action; and, as a result of his investigations, the three following points were made manifest :—

(*a*) That the rupture of a material may be produced by strains frequently applied, none of which attain unto the static breaking stress.

(*b*) That the destruction of the cohesive force of the material depends upon the range of stress between the limits of the oscillations of strain.

(*c*) That the absolute amount of the extreme tensions is only of importance in so far that the differences of strain which affect rupture decrease with the increasing tension.

The following figures, taken from Wohler's experiments, together with Fig. 1, which I have plotted from them, show clearly the relative values of alternations to stress intensity :—

ALTERNATE BENDING OF A BAR OF AXLE IRON BY THE PHŒNIX CO.

No.	Stress in lbs. Sq. inch.	Revolutions.	Remarks.
1	34,240	56,430	The last of these pieces
2	32,100	99,000	was unbroken after
3	29,960	183,145	132,250,000 revolu-
4	27,820	479,490	tions.
5	25,680	909,810	The ultimate tensile
6	23,540	3,632,588	strength of this iron
7	21,400	4,917,992	was 47,000 lbs. per
8	19,260	19,186,791	sq. inch, and the
9	17,120		elongation about 20 per cent.

It will be seen from this table that the strength is inversely as the alternations of stress, and consequently much depends upon whether or not the structure is to be permanent or temporary, or whether the stresses occur rapidly or at intervals.

Some bridges, for instance, can safely stand the passage of a given number of trains per hour, but could not stand the same number passing in one minute. It is well known that steel bridges sag somewhat during the week's heavy traffic, but recover during Sunday's quiet.

Every structure that is subjected to other than a dead unvarying load must have a high factor of safety, and this in the past has been an empirical figure based on experience rather than investigation. Wohler, however, pointed out

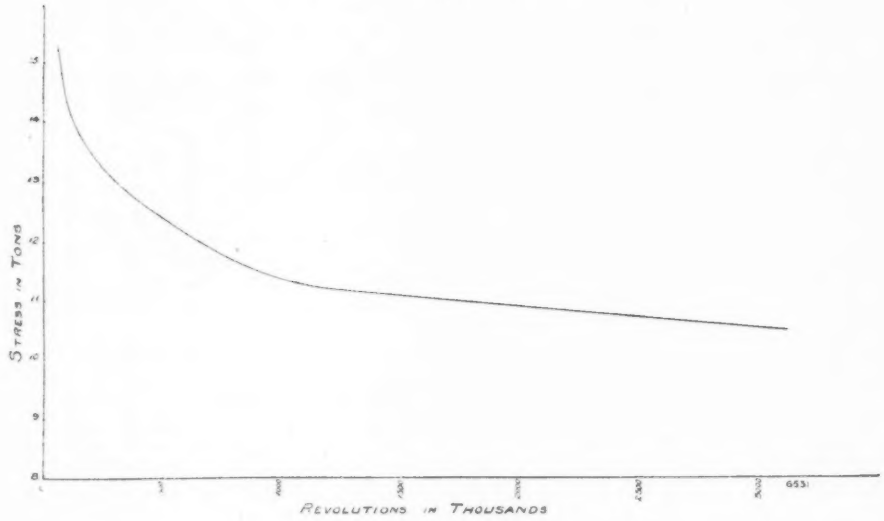


FIG. 1.—DIAGRAM PLOTTED FROM WOHLER'S EXPERIMENTS ON THE RELATION OF ALTERNATIONS TO STRESS INTENSITY.

that this factor must depend on the range of stress to which the structure is subjected; and the greater the range the larger the factor. If tensional stresses be called positive and compressive stresses negative, then on a complete reversal of stress—as, for instance, that which takes place in a piston rod of a double-acting engine in each revolution—the range of variation =

$$\Delta = f \text{ max.} - (-f \text{ min.}) = f \text{ max.} + f \text{ min.},$$

consequently the range =

$$\Delta = f \text{ max.} \mp f \text{ min.},$$

the negative sign being used for stresses in the same sense, and the positive for stresses acting in opposite senses, therefore Δ is always positive provided f min. is never greater than f max.

It may be mentioned that the spring of a watch bends and unbends over 50 million times a year, and is yet unaffected; due to the low intensity of stress to which it is subjected.

Wohler's Machines.

Torsion.

The machine shown in Fig. 2 is that upon which Herr Wohler carried out his torsional tests. It consists of a bed-plate upon the centre of which is mounted a pair of bearings one front and back, for the purpose of carrying the test bar. On the back end of the test bar—which is of circular section and has enlarged ends—is fixed a lever *a*, which is given a reciprocating motion by means of the oscillating lever *b*, through the medium of the rod *c*. The stroke of the lever *b* can be adjusted by shifting the pin of the connecting rod—by which it is driven—in the slot provided on lever *b* for this purpose. The top end of lever *c* is fitted with nuts, which have contact with knife edges on lever *a*, which are also a means of adjustment for the stroke of lever *a*.

Affixed to the front end of the test bar is the double lever *d*, the two ends of which press on the short ends of levers *e* and e^1, the ends of these latter being prevented from rising by reason of the

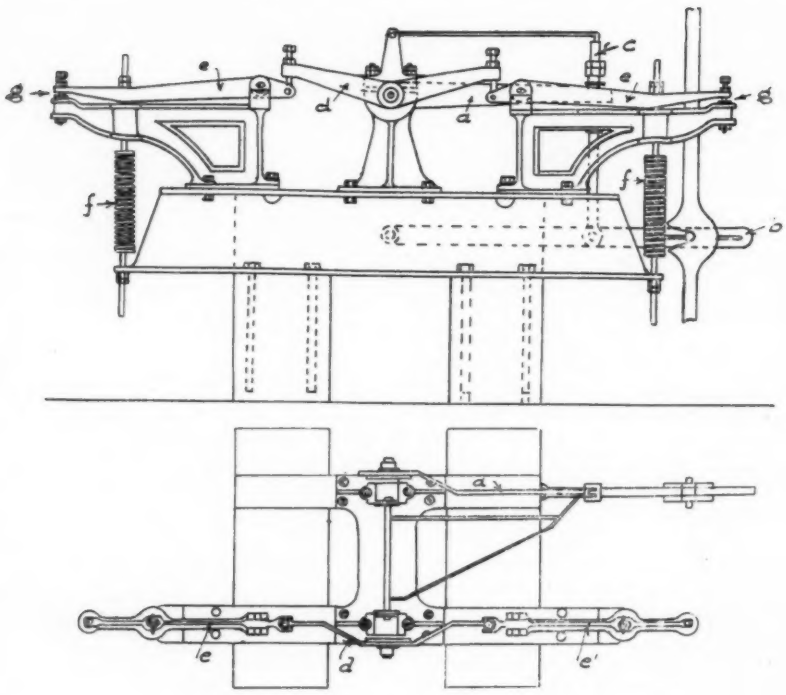


FIG. 2.—MACHINE USED BY WOHLER FOR TORSIONAL TESTS.

adjustable springs *ff*. When not in action, these levers rest on the bearing screws *gg*.

The function of levers *d*, *e* and e^1, is to prevent the bar being strained beyond a predetermined limit, as if the stress becomes too great it causes lever *d* to press on the short arm of either lever *e* or e^1, and the excess of stress is taken up by either one of the springs *ff*.

If the stroke of the lever *d* is sufficient to alternately twist the specimen either side of its unstrained position, then the levers *e* and e^1 are alternately brought into action, if the stress rises above that required. For twisting in one direction only, however, either one of the levers *e* or e^1 will suffice.

Repeating Tensions.

Fig. 3, was designed for the purpose of carrying out tension tests. It consists of a bed-plate upon which is fixed a cast-iron standard which supports the knife edge of the lever *a*, from the short arm of this lever is hung a pair of shackles for holding the upper portion of the specimen, the lower portion of the specimen being held by shackles which are connected to the adjusting screw *b*. The extremity of the long arm of the lever *a* is connected by a link to the equal armed lever *c*, the axis of which is moved vertically by means of a connecting rod ; a bent spring *d* being interposed to prevent shock. One end of this lever *c* rests on the short arm of the lever *e*, which is constrained by means of the spring *f* and adjustable bearing screw.

By adjusting the spring *f*, the force exerted on the lever *e* can be regulated, so that the pull on *c* shall not exceed the required amount. For facilitation of adjustment the rod *h* by which the pull is applied

to the beam *c* is in two parts, screwing into a nut with right and left-handed threads. The lower portion of this rod passes through a bracket, and its extremity is fitted with a nut, to enable the rod to be relieved to a greater or less extent of the stress imposed. In setting the machine, the spring *f* is adjusted to the maximum stress, and the nut on *h* screwed until it just keeps the lever *e* lifted; then the spring is adjusted to the maximum stress when it is ready for use.

By having four sets of levers Wohler was able to test four bars at the same time.

Repeating Bending Stresses.

Fig. 4 is the machine upon which he carried out tests on the effects of repeated bending. On the right of the bed-plate is the spring *f* controlling lever *a*, similar to that in the two previously described machines. From the short arm of this lever *a* is hung a pair of links to carry one end of the bar to be tested, the other end of the bar being carried by a similar pair of links hung from a fixed bracket. The rod *b* —which is attached to, and moved by, a lever at its lower end —acts upon the specimen through the medium of an adjustable coupling.

Should it be required to strain the bar between an upper and lower limit, and never to quite release it of the load, the screw *c* is utilised so that upon the bar unbending it comes into contact with *c*, and consequently is unable to straighten beyond a given deflection.

To set this machine, a balance is first made between the minimum stress of the spring *f*, and the pressure of the screw *c* on the specimen, and the maximum stress then set on the spring when the machine is ready for use.

Repeating Bending in opposite directions.

This machine, shown in Fig. 5, consists of an axle *a*, which is rotated through the medium of the pulley. In each end of this axle is a conical recess into which the bars to be tested are fixed, afterwards being turned to ensure true running. At the extremity of each bar is attached a spring *f*, which are capable of being adjusted to any required stress. As the bar rotates, every fibre is subjected to bending in alternately opposite directions.

The tensional test-bars as used by Wohler are as shown at *a*, Fig. 6, in which it will be seen that the change of section is gradual and not sudden, as this, he found, reduced the strength from $\frac{1}{3}$ to $\frac{1}{4}$ of the plain bar.

The specimens tested, from the results

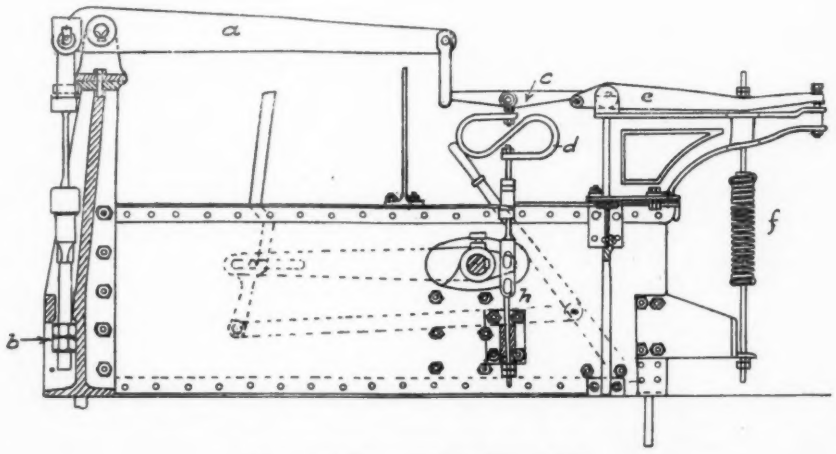


FIG. 3.—WOHLER'S MACHINE FOR TENSION TESTS.

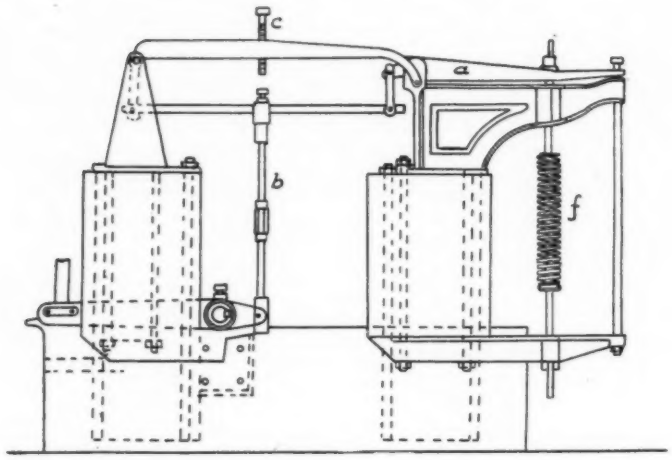


FIG. 4.—WOHLER'S MACHINE FOR REPEATED BENDING TESTS.

of which the table accompanying Fig. 1 was obtained, were of the form shown at *b*. The portion driven into the rotating shaft was in all cases 1½ diameter, and slightly tapered, and the reduction in the section was gradual.

Another test-piece, exactly similar in all respects, with the exception of the reduction in section being made sharp as at *c*, showed signs of fracture after 4,315,359 revolutions at a stress of 21,400 lbs.

It may be mentioned that the machine ran at 72 revolutions per minute for these tests.

Wohler's experiments were confirmed by Spangenberg and Bauschinger; the former of whom continued and extended the work on Wohler's own machines, which, it may be mentioned, are now in the Charlottenburg Laboratory, and are still in use; the latter constructed machines of the same kind, and also agreed with Wohler's conclusions. He also found that a material stressed beyond the elastic limit in one direction lowers the elastic limit when stressed in the opposite direction; it thus follows that, by repeated alternations, the strength is lowered in both directions and at the limit the value agrees with those found by Wohler for alternating stresses.

Unfortunately, Wohler's experiments, although extensive, were not carried out on a sufficient variety of materials to be of universal use, his experiments being restricted to iron and steel; and the results of his tests cannot be generalised, as it is unsafe to assume that the behaviour of a metal will be the same under different kinds of strain; and, therefore, to make experiments of one kind and deduce values for others—which was Wohler's idea—is certainly not feasible, and his results therefore must be used only for the same materials as those tested. He found that wrought iron having an ultimate tensile strength of 19·5 tons would stand an indefinite number of alternations of stress, provided the limits did not exceed the following:—

	Stress in tons square inch.
Alternating load	+ 7 to − 7
Load varying between zero and maximum	13 to 0
Load varying between limits	19 to 10½

Therefore it follows that the relative values of the maximum load vary approximately as 1:2:3, and for steel Wohler found results of a similar kind.

Wohler's experiments on alternating

twisting show that the strength of the various steels tried was $\frac{4}{5}$, that when subjected to alternative bending; and from this it is universally assumed that the resistance to shearing is $\frac{4}{5}$ the resistance to tension.

It should be noted that in the cases of unlimited repetitions the resistance to stretching is the same as the resistance to bending, but the resistance to twisting, less.

Impact.*

The cumulative effect of shocks must not be confused with fatigue. If the shock resulting from the kinetic energy of the blow be more than can be absorbed by the elastic property of that portion of the structure where it occurs, the elastic limit will be exceeded and local hardening will occur; and if sufficiently repeated may finally cause the collapse of the material. This may be shown graphically by means of an ordinary stress-strain diagram, as in Fig. 7, where the abscissæ are the strain and the ordinates the stress. The point E is the original elastic limit, and up to this point the stress and strain are proportional. If therefore the stress produced by the first blow rises to E^1, the area OEE^1X will represent the energy of the blow. The effect of this blow is to raise the limit from the stress EY to the stress E^1X nearly. Therefore the curve becomes OF, where F is the new limit due to the hardening of the material, and it will only bear a blow the energy of which is represented by the triangle OFZ without the original stress E^1X being exceeded. Thus by constant repetitions of a stress a little in excess of the original elastic limit, the final collapse of the material may be produced.

It is a question amongst engineers whether, in Wohler's experiments, the internal stress was really limited to the required amount without exceeding it, and whether or not dynamic stresses (or impact) were introduced every time the specimen was subjected to the load; but in the writer's opinion the experiments of Wohler were fatigue tests only, and dynamic stresses were not set up.

*A description of a machine for impact testing, designed by Mr. Bent Russell, can be found in Vol. xliii, p. 1 of the *Trans. American Inst. of Civil Engineers.*

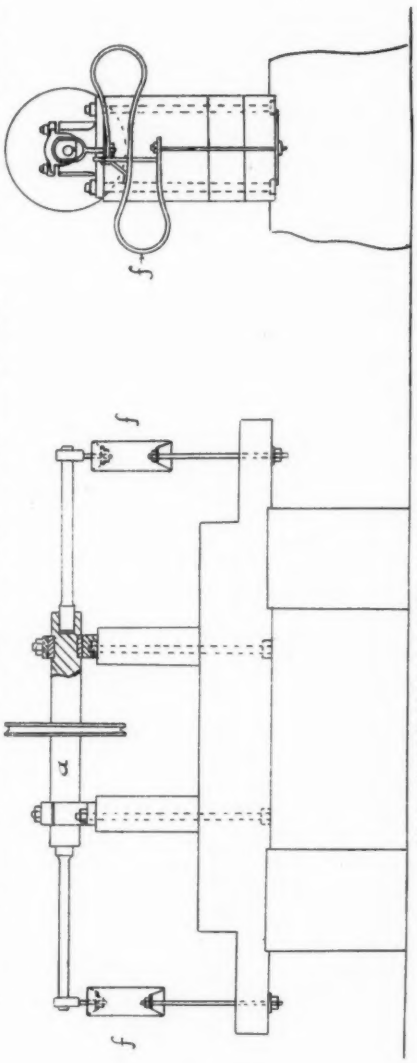


FIG. 5.—WOHLER'S MACHINE FOR TESTING REPEATED BENDINGS IN OPPOSITE DIRECTIONS

It is also a matter of controversy at the present day whether it is necessary to allow for impact in addition to fatigue, but it is found in bridge work that the members become exceedingly — and unnecessarily —large when both are allowed for, and

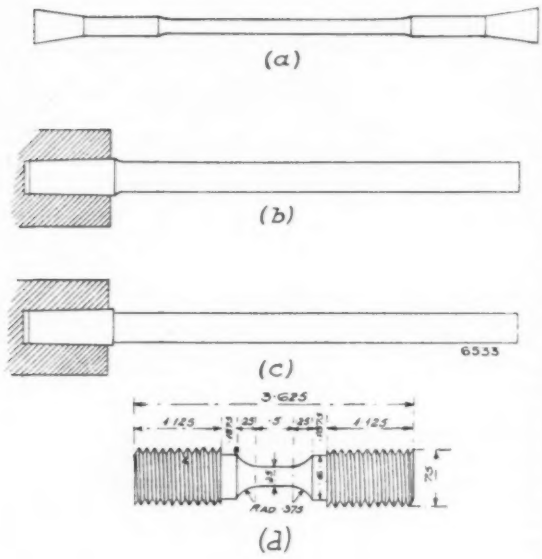


FIG. 6.—TEST PIECES AS USED BY WOHLER.

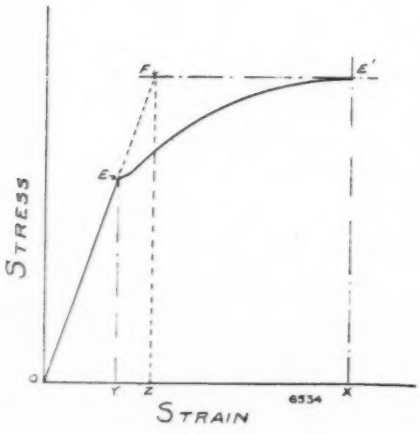


FIG. 7.

therefore it is found that, as the strains are intermittent, the allowance for fatigue covers impact. The stresses allowed for in bridge work are, in the case of wrought iron, only 5 tons, and for steel 6½ tons per square inch. It may be here mentioned that Lippold by the following hypothesis arrived at the same conclusions as Wohler concerning a variable strength :—"To break a bar a certain amount of mechanical work is necessary, and this can be accumulated in the material at once just as well as by repeated loads. These loads must, however, be applied instantaneously, or so rapidly that vibrations arise."

It will be seen from this that vibrations are essential to the theory, whilst no weight is attached to the number of repetitions occurring. This, therefore, is an impact test, and it is interesting to note that the formula arrived at by Lippold shows that the strength varies in a similar manner as if based on Wohler's law.

It has been found that iron under a variable stress, however small and slowly applied, has its magnetic and thermodynamic qualities changed in an irreversible manner, and no doubt there are mechanical effects also, which, however, are not detectable. This — together with the fact that under an applied stress a bar becomes heated due to the work done upon it, and consequently loses this amount of energy—tends to show that perfect elasticity does not exist, at any rate between wide limits.

A period of rest on a fatigued structure tends to restore elasticity, but whether it also tends to restore strength — without first annealing—is not known; it is, however, unlikely that even annealing will bring the material back to its normal condition if cracks have once seriously started.

Professors Ewing and Muir found that a few minutes' immersion of a fatigued bar in hot water effects a recovery, showing that high temperatures in some cases are not necessary.

It is necessary, in finding a rational formula, that the experiments undertaken

for the purpose shall be carried out on the same materials and under the same conditions, so that the effects of varied stresses can be noted, because—as already mentioned—the results so far are not capable of being generalised.

In the formula used hereafter the following meanings will be attached to the various symbols :—

f = the statical breaking strength of the material.

f max. = breaking strength of the material when subjected to a variable load and unlimited repetitions.

u = primitive strength, being the resistance of the material under a given number of repetitions of stress, all of which are the same in sense.

s = the vibration strength, or resistance to repeated stresses of equal intensity which are alternately different in sense.

Note.—If the stress in one direction becomes zero, $s = u$.

k = unknown co-efficient.

ϕ = ratio between maximum and minimum stresses.

Δ = range of stress.

Launhardt's Formula.

For stresses in one sense only.

A bar of unit area is subjected to stresses which are either purely tension, compression, or shearing, and which vary from f max. to f min.

Let f max. $- f$ min. $= \Delta =$ max. dif. of stress, and let the ratio $\frac{f \text{ min.}}{f \text{ max.}} = \phi$.

Then if f min. $= o$, f max. $= \Delta = u$.

,, $\Delta = o$, f max. $= f$ min. $= f$.

By Wohler's law :—

$$f \text{ max.} \propto \Delta = k\Delta \quad \ldots \quad \ldots \quad (1)$$

K being an unknown co-efficient which Launhardt assumed was equal to $\frac{f-u}{f-f \text{ max.}}$, when

$\Delta = o$, f max. $= f$ and $k = \infty$

$\Delta = u$, f max. $= \Delta$ and $k = 1$

this satisfies these extreme conditions, and it also gives intermediate values of f max., which closely agree with experiment. Therefore, putting this value in equation (1) he got :—

$$f \text{ max.} = \frac{f-u}{f-f \text{ max.}} \Delta = \frac{f-u}{f-f \text{ max.}} (f \text{ max.} - f \text{ min.}),$$

$$\text{therefore } f \text{ max.} = u\left(1 + \frac{f-u, f \text{ min.}}{u, f \text{ max.}}\right)$$

$$= u\left(1 + \frac{f-u}{u}\phi\right) \quad \ldots \quad (2)$$

and this is Launhardt's analytical expression of Wohler's Law for stresses in one sense only.

Weyrauch Formula.

For stresses different in sense.

If a bar of unit area be subjected to stresses which are alternating in sense and which vary from f max. positive of the one sense to f max. negative of the other, then—

$(f \text{ max.} +) + (f \text{ max.} -) = \Delta =$ max. numerical value of stress.

The ratio $\frac{f \text{ max.} -}{f \text{ max.} +} = \phi$.

(Note.—The ratio is always $\frac{\text{less}}{\text{greater}}$ without reference to sign.)

Weyrauch's assumption that

$$k = \frac{u-s}{2u - s - (f \text{ max.} +)} \quad \ldots \quad (3)$$

satisfies the following extreme conditions, when f max. $- = o$, f max. $+ = \Delta = u$,

f max. $- = s$, f max. $+ = s = \frac{\Delta}{2}$,

if f max. $+ = o$, $k = 1$,

f max. $+ = s$, $k = \frac{1}{2}$.

By putting the assumed value (3) into Wohler's law (1), he got—

$$f \text{ max.} + = \frac{u-s}{2u - s - (f \text{ max.} +)} \Delta =$$

$$\frac{u-s}{2u - s - (f \text{ max.} +)} [(f \text{ max.} +) + (f \text{ max.} -)],$$

and therefore

$$f \text{ max.} + = u\left(1 - \frac{u-s, f \text{ max.} -}{u \quad f \text{ max.} +}\right) =$$

$$u\left(1 - \frac{u-s}{u}\phi\right) \quad \ldots \quad \ldots \quad (4)$$

This is his formula, and is always applicable where any part of a structure is to withstand alternating stress actions, whether between tension and compression or shearing in opposite directions, and it will be seen that the maximum allowable stress decreases as the range of stress

increases, and *vice versâ* in accordance with Wohler's deductions.

Unwin's Formula.

If the ranges of stress are plotted as ordinates, and the minimum stress as abscissæ, the points fall on a parabola, and a formula to fit this was found by Gerber, and is known as "Gerber's Parabolic Equation" which has been adopted by Unwin and is as follows:—

$$f \text{ max.} = \frac{\Delta}{2} + \sqrt{f^2 - n\,\Delta\,f}$$

for a static load Δ of course equals zero, and f max. $= f$,

for fluctuating load varying between zero and maximum $\Delta = f$ max. and approximately when $n = 1{\cdot}5\,f$ max. $= \frac{8}{9} f$,

for an alternating load varying between f max. + and f max. − :— $\Delta = 2\,f$ max. and when $n = 1{\cdot}5\,f$ max. $= \frac{1}{3} f$.

It will be seen from the above three cases that the relative values of a static load, a variable load, and an alternating load, vary approximately as 1 : 2 : 3, which, as already mentioned, was the ratio as found by Wohler.

n is here a constant for the various materials deduced from Wohler and Bauschinger, the most important of them being given in the annexed table, where W and B show from whose work n was deduced.

VALUES OF n.

Material.	Tensile strength in tons.	n =.
Phœnix iron	22 8	1·33 W
Krupp axle steel	52	1·83 W
Spring steel (untempered)	57·5	2·4 W
W.I. plate	22·8	1·6 B
Bessemer steel...	28·6	1·68 B
Bar iron	26	1·67 B
Steel axle...	40	1·91 B
,, rail	39	2·0 B
,, boiler plate	26·6	1·53 B

In an interesting Paper read before the American Society of Engineers, in 1887, Sir Benjamin Baker gave the results of his own experiments — carried out on a machine similar to Fig. 5—which, like those of his predecessors, confirmed Wohler's original results.

Most test pieces which he used for alternating bending were 1 in. diameter, and projected 10 ins. from the support—*i.e.*, the shaft. A speed of about 50 to 60 revolutions per minute was maintained day and night, and flat bar specimens for bending laterally were 1 in. by ½ in. and 32 ins. long between supports.

It is well known that, if a piece of material is repeatedly strained and released the elastic limit each time being *exceeded*, the ultimate breaking strength is raised and the elastic limit may ultimately become equal to practically the breaking strength itself. His experiments, however, quite disprove the prevailing idea that alternating stresses are not harmful if kept *below* the elastic limit, as some of the stresses in his experiments were far below it, although sufficient to cause rupture.

Hard steel he found to have only about 10 per cent. more strength that soft steel of only half the tensile strength after being subjected to the same number of alterations of stress.

Prof. Ewing and Mr. J. C. W. Humphrey, in a valuable Paper read before the Royal Society in 1903, gave the results of their recent investigations in this subject. The tests which they carried out were on Swedish iron of high quality, having a statical breaking-strength of 23·6 tons per sq. in. (on the original area), an extension of 26·6 per cent. in a length of 8 in. and a contraction of area of 61 per cent.

The test bars were in the form of rectangular rods measuring 0·3-in. by 0·1-in., and were first prepared by annealing in a muffle furnace, being enclosed in a tube of lime, and the whole kept at a dull-red heat for two hours. One face of each rod was polished and etched prior to its being subjected to alternating straining actions, so that under test the polished surface was alternately stretched and compressed. The machine used was of a similar form to Wohler's, shown in Fig. 5, and ran at 400 revolutions per minute. Professor Ewing in conclusion says:—

"Whatever the selective action of the stress is due to, the experiments demonstrate that in repeated reversals of stress certain crystals are attacked and yield by slipping, as in other cases of non-elastic strain. Then, as the reversals proceed, the surfaces upon which slipping has

occurred continue to be surfaces of weakness. The parts of the crystal lying on the two sides of each such surface continue to slide back and forth over one another. The effect of this repeated sliding or grinding is seen at the polished surface of the specimen by the production of a burr or rough and jagged irregular edge broadening the slip band and suggesting the accumulation of *débris*. Within the crystal this repeated grinding tends to destroy the cohesion of the metal across the surface of slip, and in certain cases this develops into a crack. Once the crack is formed it quickly grows in a well-known manner, by tearing at the edges, in consequence of the concentration of stress which results from lack of continuity.

"The experiments throw light on the known fact that fracture by repeated reversals or alternations of stress resembles fracture resulting from a 'creeping' flaw in its abruptness, and in the absence of local drawing out or other deformation of shape."

The formation of cracks, however, appears not to be so serious in the case of unidirectional stress, as in the case of alternating stress, there being some especial weakness induced by reason of the alternations.

It is a curious fact that a piece of material after being fatigued by varying stress actions and has nearly arrived at its limit of endurance, does not appear to show any marked deterioration either in its tensile strength or its plastic properties when tested by the static method. This, says Professor Ewing, is not to be expected so long as the reversals have not been sufficient to produce a crack, but it will have a yield point corresponding to the amount of permanent extension it has received.

M. Fremont's method of testing, which he has adopted by reason of the unsatisfactory static method, and the cost, is by bending small bars of square section; carried out by means of a machine which is an adaptation of an ordinary punching machine. The bar to be tested is supported horizontally on two blocks mounted on the bed, and in place of a punch a blunt vertical chisel is used rather broader than the specimen upon which it acts. The test bars are 0·3937 in. by 0·314 in. and 1 in. long. These bars are easily and cheaply cut from waste fragments.

Professors Heyn and Arnold also test by distorting the specimen, the former in testing pure iron repeatedly bending through an angle of 90 degs. on a notched bar, whilst the latter in testing steel used plain bars and bent through a smaller angle. Bending to distortion does not appear a fair method, as in practice no structure is so distorted; therefore, until results are obtained agreeing fairly well with those already known, too great reliance should not be placed upon them.

The results of Stead and Richards' experiments on the restoration of steel dangerously crystalline, are extremely interesting; and an account of them will be found in Vol. IX., p. 306, of this magazine. The machine upon which they carried out their fatigue tests was made by Messrs. Richardsons, Westgarth & Co., a drawing of which may be found in the above-mentioned article. The test bars as used, were short, being about 3 or 4 ins. long, and $\frac{1}{2}$-in. diameter, a groove being turned in the centre to a diameter of $\frac{3}{8}$ in., this being polished till all scratches were removed. One end of this bar is fixed to the spindle of the machine whilst the other has an extension piece attached, which carries the weight. The speed of working was 2,000 revolutions per minute.

Professor Reynolds and Mr. J. H. Smith, carried out alternating tests, by causing the specimen to reciprocate a dead weight in a straight path. The machine consists of two weights moving in straight lines at right angles to each other, the specimen forming a connecting link between one of the crossheads and the weight reciprocated thereby, the other weight being simply for the purpose of balancing the first. It is run off a rotating crank-shaft, by means of two connecting rods having a common centre at the crank-pin, and the motion is practically periodic. The alternating stresses are approximately equal, and the number of alternations is limited to 2,500 per minute, being partly due to the vibrations produced by higher speeds.

An extremely valuable Paper giving the above machine in detail, together with the results of the tests carried out, was read before the Royal Society in 1902*, and the form of test bar most commonly used is shown at *d*, Fig. 6.

* Throw-testing machine for reversals of mean stress. Prof. Reynolds and J. H. Smith, Royal Society, Vol. 190, Series A, p. 265.

A new type of testing machine for alternating tension and compression, driven by steam, can be seen in Vol. 10, page 435 of this magazine, being an abstract of a paper by Mr. F. Foster. It appears to have many advantages, chief among them being that the frequencies of loading are high and can be varied; frequencies and loadings independently. There are no reciprocating parts, and the limits of alternations may be obtained by slightly modifying the machine.

The speed at which fatigue tests are carried out vary to an enormous extent with different experimenters, some of Wohler's being as low as 8, and Stead and Richards' as high as 4,000 alternations per minute.

It is, however, interesting to note that some of Wohler's experiments for the purpose of finding the effect of speed on the test bars are quite the reverse of what would naturally have been expected. Instead of driving the axle *a* of the machine, illustrated in Fig. 5, continuously, it was arranged to run so that during three-quarters of the time of a complete revolution the bar remained stationary, thus allowing it time to somewhat recover. The two followivg cases, when compared with the third and fifth results in the table accompanying Fig. 1, seem to show that the higher the speed the more capable is the material of withstanding an alternating stress. Mr. Smith's experiments, however, bear out the opinion that, at very high speeds, very few repetitions suffice to cause rupture, whereas low speeds require an enormous number. It is, of course, possible that the effect of a partial rest on the test bar was injurious; but, although interesting, no reliance should be placed on these results of Wohler's until verified by similar experiments.

Stress in lbs. per sq. in.	Revolutions with intermittent motion.	Revolutions of No. 3 and 5 taken from table.
29,960	170,900	183,145
25,680	610,000	909,810

This experiment shows that in the first case the continuous test was 6·68 per cent. stronger than that running intermittently, and in the second case a difference in favour of continuous running of 32·9 per cent.

As the experiments recently carried out are for the most part on the same style of machines as those of Wohler's, already described, it is unnecessary to deal with them individually.

The experiments so far carried out in this all-important branch of the strength of materials, of late years have been in many able hands, amongst whom may be mentioned Sir Benjamin Baker, Professor Ewing and Humphrey, Professor Reynolds and Smith, and others in this country; and by Fremont, Russell, and others both on the Continent and America; but the results obtained have not brought forth an improved formula of a general character; the information being rather of a microscopical nature as regards the actual behaviour of, and effect on, the materials when under test, and this is no doubt the correct starting-point for investigation. All the formulæ, however, as now used are empirical, and the data is not extensive enough to give them very much value, although they agree fairly well with the experiments so far carried out; but in the writer's opinion Unwin's formula—which is used in England—although not the acme of perfection, partly by reason of the constants necessary for the various materials, is, nevertheless, more handy and nearer what is required than the older Launhardt-Weyrauch formulæ, which, it may be mentioned, are used extensively in America.

It is to be hoped, however, that the results of the experiments now being carried out, together with those already obtained, may lead to the adoption of a simple formula in the near future, which will be universally accepted as satisfactory, both by those who now use the older formulæ, and also by those who regard the results so far obtained as being unsatisfactory, and who are consequently compelled to judge by experience.

Fire-Resisting Construction.—II.

By W. NOBLE TWELVETREES, M.I.Mech.E.

THE high resistance offered by concrete renders this one of the most useful materials at the disposal of the engineer; and, when reinforced by steel, either in the form of rods as adopted in the Hennebique system, or of rods and metal network, as employed by the Expanded Metal Company, the weight and bulk of material used can be very largely reduced without sacrifice of strength or safety.

Expanded steel is admirably adapted for the construction of foundations, walls, columns, beams, floors, partitions, ceilings, roofs, and indeed for almost any part of the framework of a building.

It is now an established fact that a fire-proof factory building can be erected at almost the same cost as one built on the old-fashioned combustible system. By using properly protected steel columns placed on reinforced concrete foundation slabs, and by the aid of adequate engineering skill, it is possible to erect fire-resisting factory buildings with plenty of light in the side walls as well as in the roof, and with a maximum amount of advantage in other directions. The best type of side wall for buildings of this class is the monolithic wall of steel and cement mortar. The steel consists of $\frac{3}{8}$-in. round or $\frac{3}{4}$-in. flat bars placed at 12 in. to 16-in. centres, upon which is laced a fabric of expanded steel lath, and upon this the cement mortar is spread to form a slab of from 2 ins. to 3 ins. thick. The roofs should be of steel framing, carrying a slab of reinforced concrete on spans ranging from 5 ft. to 20 ft., according to the general design of the building.

Fig. 1 is reproduced from a photograph of a retort house, built by the Expanded Metal Company at the Dublin Gas Works, and is a fair example of what can be done by the judicious employment of steel skeleton framing and expanded steel lath and cement plaster filling. This building is 86 ft. long by 56 ft. wide by 32 ft. high to the eaves. The steel framework was first erected, and then covered in and encased with expanded metal lathing and cement plaster. The walls were formed of 3 ins. of plaster laid on expanded metal lathing, which was tied with copper wire to horizontal tension rods, $\frac{3}{8}$-in. diameter, stretched 12 ins. apart from stanchion to stanchion. This system of construction gives a fire-resisting structure, light, strong, and economical, and it should be noted that no inflammable material of any description is required, as the framework, sashes, doors, etc., are all of steel.

It is an acknowledged fact that the effects of fire are felt by floors more severely than by any other structural details in a building. We therefore append

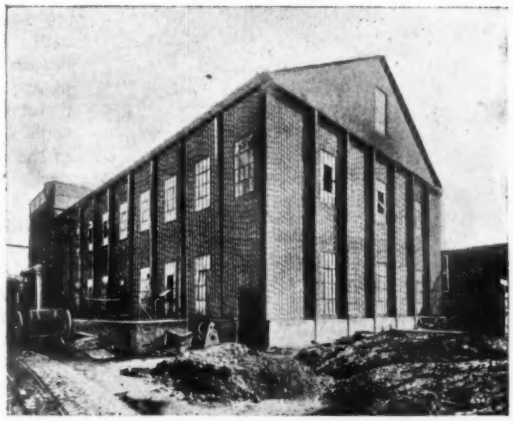
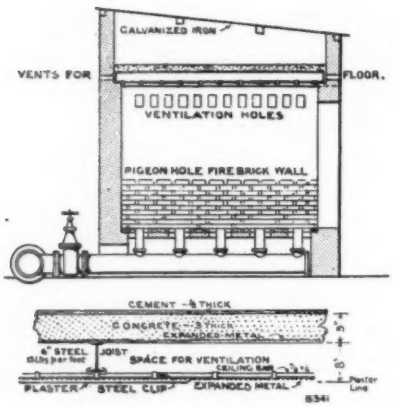


FIG. 1.—RETORT HOUSE AT DUBLIN GAS WORKS: STEEL FRAMEWORK, EXPANDED STEEL LATHING, AND CEMENT PLASTER CONSTRUCTION.



FIGS. 2 AND 3.—DETAILS OF FIREPROOF SYSTEM, EXPANDED METAL CO.

some brief particulars, taken from the official reports of the British Fire Prevention Committee, relative to the test made upon an expanded metal floor in February, 1899.

Fig. 2 is a section showing the floor as built in a brick chamber at the testing station. The floor was formed of a 3-in. concrete slab, supported by three 6-in. by 3-in. steel joists, these being protected by an expanded metal and mortar ceiling. Fig. 3 shows the details of the floor and ceiling construction.

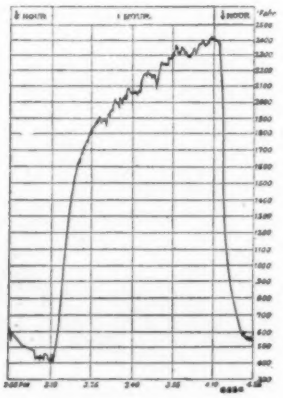


FIG. 4.

The object of the test was to record the effect of a smouldering fire of 15 mins. duration at a temperature not exceeding 600 degs. Fahr., followed by a fierce fire of 1 hr., gradually increasing to a temperature of 2,000 degs. Fahr., followed suddenly by the application for 3 mins. of a stream of water, the floor being loaded to 140 lbs. per sq. ft.

Fig. 4 is a diagrammatic log of the test, the results of which may be thus summarised :—

The plaster ceiling below the floor remained intact until the application of water, there was a slight deflection of the floor and ceiling, and the concrete of the floor was slightly and superficially cracked, but the fire did not pass through the floor.

Another excellent system of fireproof floor is that adopted by the Columbian Fireproofing Company. The Columbian system of fireproof floors consists of special ribbed steel bars suspended in steel stirrups over steel joists and between main girders, or resting on walls. By the use of heavy ribbed bars ordinary floor joists are eliminated. These bars are surrounded by and embedded in concrete, thereby forming a monolithic fireproof floor.

Three types of fireproof floors are made by this firm : (1) panelled floors (Fig. 5) for warehouses and similar buildings ; (2) double-construction floors (Fig. 6), with level ceilings of concrete under and between the joists, with a close spacing of joists ; and (3) ribbed-bar floors (Fig. 7), formed between the main girders and walls by using heavy ribbed bars instead of the usual rolled-steel joists.

Although the Columbian fireproof floor is not an entirely new type of floor, it possesses valuable fire-resisting properties, and combines the important qualities of strength and economy ; and its cost is so moderate that the use of fireproofing can now be made by those who have hitherto been deterred by considerations of expenditure.

There are several fireproof floor systems in which hollow lintels of fireclay or terra-cotta are employed between the girders, and the spaces left are filled with concrete ; the floor being covered below with

plastered or cement ceiling, and above by cement or timber floor-boards.

The Fawcett ventilated fireproof floor is formed of tubular terra-cotta lintels which can be placed very rapidly between ordinary rolled joists. The lintels are formed so as to permit the concrete filling to be supported by the lower flanges of the joists, and to afford a satisfactory key for the plaster ceiling formed on the under side of the floor. Fig. 8 is a transverse section showing the concrete bearing on the bottom flanges of the joists at *A*.

The joists generally used have flanges of equal area and shape, and these have, until recently, been employed. Messrs. Fawcett & Co. have found, by practical tests, that when the floor is subjected to a heavy load, the upper parts of the joists are strengthened by the concrete, whilst the lower part is not so aided, owing to the concrete being capable of resisting great compressional stresses but not great tensional stresses. Hence, the system now employed (and by which a great economy of steel is effected and the fire-resisting properties increased) is to use joists with small upper and large lower flanges. The latter not only offer more resistance to tensional stresses, but take longer to become heated. Messrs. Fawcett have obtained a patent for this new combination which is now being largely adopted.

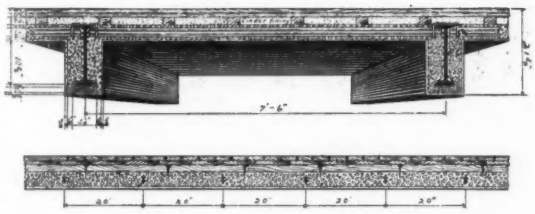


FIG. 5.—PANELLED CONSTRUCTION: SOLID CASING.

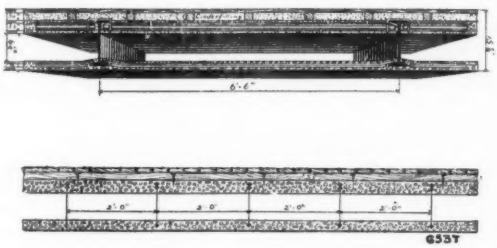


FIG. 6.—FLAT CEILING CONSTRUCTION.

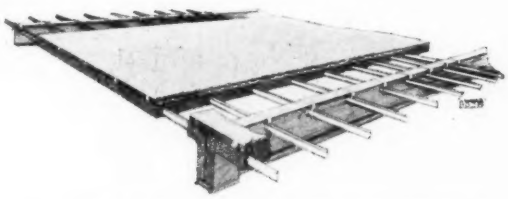


FIG. 7.—FLOOR WITH HEAVY RIBBED BARS SUSPENDED IN STIRRUPS.

In the Homan fireproof floor system a hollow fireclay block of triangular section is employed in the manner shown by Fig. 9, which is a perspective sketch illustrating the general method of construction.

The M. - P. fireproof keyed lintel floor and ceiling is formed, as shown in Fig. 10, with hollow tiles or lintels made from mild tempered clay, and capable of sustaining a temperature of 2,000 degs. Fahr. The lintels are slotted through each end, so as to bear upon the bottom flanges of rolled steel joists, which are thus encased and protected from exposure to fire. Being of dovetailed shape the lintels form a strong key for the concrete, which when set also supports them.

All the foregoing systems possess the advantage that there is no outward thrust against the walls, as occurs when arched floors are employed. They are extremely simple, and are of great strength, while their fire-resisting qualities have been

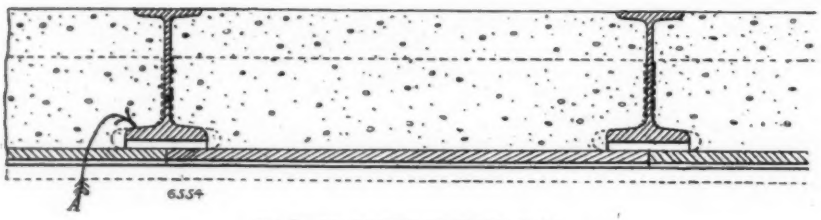


FIG. 8.—THE FAWCETT VENTILATED FLOOR.

amply proved by satisfactory behaviour in many severe fires.

Dawnay's solid tile fireproof floor, designed by Mr. Archibald D. Dawnay, A.M.Inst.C.E., consists of solid fireclay tiles placed between girders and filled in solid with concrete, as illustrated in Fig. 11.

Fig. 12 shows the details of construction of the Potter Fireproof floor, type A, in which the bottom flanges of the joists are encased by burnt-clay shields. A hanging ceiling of expanded metal lathing is fixed to steel bars, secured by hangers, leaving a hollow space between the floor and ceiling. The joists are thoroughly protected from fire; and, as the concrete is under compression only, there is no waste of material and considerable strength is secured.

In Banks' fireproof floors the essential feature is the interposition of a fire-checking ceiling virtually separated from the floor to be protected. Between ceiling and metal joists of the floor is a clear space of not less than $2\frac{1}{2}$ ins. This permits the free circulation of air above the ceiling, and the floor remains unaffected by heat below. The ceiling is formed of helical metal lathing attached to light ceiling bars, made in short lengths to allow for expansion. The girders which support the joists are also protected from fire by being encased in helical lathing and plaster.

Many forms of floor construction besides those mentioned above are available, in which concrete generally forms the fire-resisting and filling material, while resistance to bending moments is chiefly afforded by different manufactured forms of steel. Space will not permit us to make detailed mention of these, and we must now pass on to consider some other details of structural work for which fire-resisting materials and methods have been applied.

In the construction of what are generally termed "fireproof" inner walls and partitions, two general methods are adopted. One is to provide a light frame-work of steel meshing or rods, which is coated with concrete, tile, asbestos, silicate cotton, or some other non conductive and heat-resisting substance, and the other is to build up the partitions of blocks or slabs of fire-resisting material, which are formed so as to interlock, or are otherwise suitably connected together.

Among the former class we may mention the systems employed by the Expanded Metal Company and various concrete-steel firms. In addition to expanded metal, other types of sheet-steel lathing—such as the "Jhilmil" steel lath (Fig. 13) manufactured by Messrs. Hayward Bros. & Eckstein—are now used in the erection of partitions, ceilings, and protective guards for girders and columns; and the patent dove-tail corrugated sheeting (Fig. 14) solely made by the Fireproof Company, Ltd., York Buildings, Adelphi, W.C., to serve as the basis for partitions, as well as for various other purposes in the fire-proofing of buildings.

This system of construction is one in which sheets of steel are formed into dove-tail corrugations of two sections, deep and shallow. The advantages secured are very great strength, a perfect double key for whatever kind of plastic material that may be employed as a covering, and a saving in space, inasmuch that as a partition it may be finished at not more than 2 ins. in thickness, and by

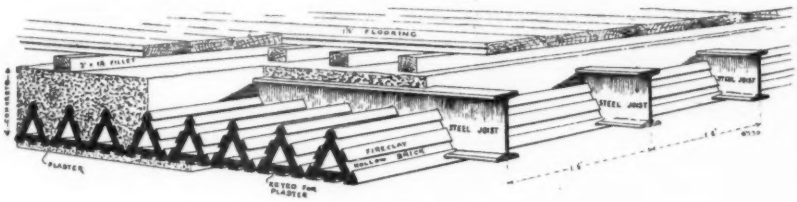


FIG. 9.—DETAILS OF THE HOMAN SYSTEM.

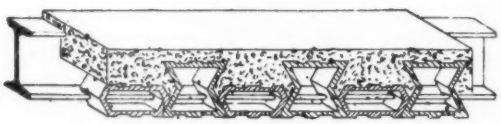


FIG. 10.—THE M.-P. SYSTEM: VIEW OF LINTELS SHOWING CONCRETE KEY BEARING ON LINTELS.

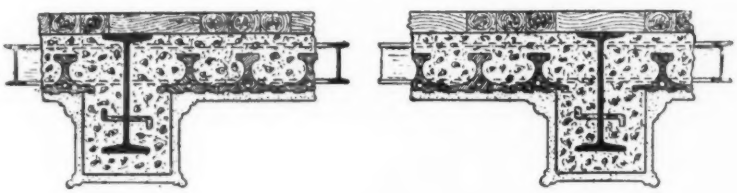


FIG. 11.—DETAILS OF DAWNAY'S FLOOR.

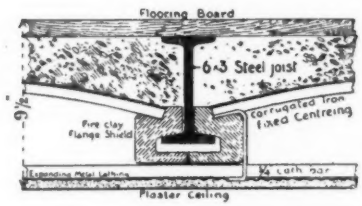


FIG. 12.—THE POTTER FIREPROOF FLOOR.

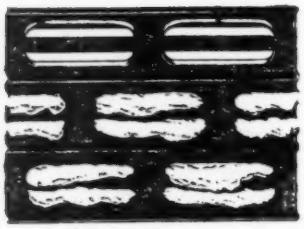


FIG. 13.—THE "JHILMIL" STEEL LATH, SHOWING PART PLASTERED.

addition to the plastic material to any required thickness. For the erection of a partition the deep sheeting is used and is erected in the following manner:—A T steel bar is fixed along the ceiling, channel section shoes being fixed on the floors under each H section upright. The H section uprights, or standards, are spaced according to the width of sheeting employed, viz. 2 ft. to 3 ft., or as may be required to fill in any space. The sheeting is placed between the flanges of the H standards, and the whole when erected forms a rigid structure, and which, being covered with any form of plastic material, becomes damp-proof, sound-proof, vermin-proof, and fire-proof. The metal sheets form one solid shield quite impenetrable to flame, and even if, under the combined effects of heat and water, the thin setting coat of plaster may be dislodged, the dove-tails effectively retain their portion of plastic material, which, owing to its form, is impossible to move under ordinary circumstances.

The shallow section sheeting is employed chiefly for the construction of fireproof floors, ceilings, girder castings, etc. For floors the simple method of laying between the flanges of R. S. joists spaced about 2 ft. 6 ins. apart is the one chiefly adopted. The sheeting forms a

FIG. 14.—SECTION OF DOVETAIL CORRUGATED SHEETING MADE BY THE FIREPROOF CO.

permanent centering for the concrete which is filled in over to any required thickness; the dove-tail sheet serving at the same time as a tension bond to the concrete. The advantage of this is apparent, as the bond is then well below the "neutral axis" of the compressive and tensile strains upon the concrete. It is necessary that the bond should be as far below such centre line or axis as possible. If, in the event of a fire and the consequent application of water, the concrete should crack, as it is liable to do, the dove-tail sheeting will effectively prevent any fall; and, also, such a bond is necessary as against plain concrete, which is at all times subject to various vibrations or concussions under which it may prove defective at its weakest point, which may be termed the under or tensile side.

The sheeting may be suitably employed to reinforce concrete under all conditions, whether as floors or walls. Complete buildings with or without steel framework have been erected upon the system as employed for the partitions, the interior and exterior being plastered to a total thickness in most cases of 3 ins., sand or cement being used as the outside covering. The roof was constructed with shallow section dove-tail sheeting carried by the H section bars used as purlins, the floors being upon the same principle as described above. Such buildings are complete effective fireproof constructions. By virtue of the light weight, much saving is effected in the foundations.

For covering the skeleton of a partition there are many kinds of fire-resisting material suitable for application in the form of sheets or of plaster.

The asbestos cement sheets, produced by the British Fibro-Cement Syndicate, constitute an excellent fireproof lining for walls, ceilings, partitions, doors and ventilating shafts. They measure about 8 ft. by 4 ft. by $\frac{3}{16}$ thick, and can easily be cut down by a saw to any size, and render partitions sound-proof and damp-proof as well as fireproof. The sheets are of such a rigid nature that, when nailed to standards or studded, they actually increase the strength of the structure. They have been adopted by

the War Office and Admiralty after careful tests for Government buildings at various places in the United Kingdom. The sheets are also excellently adapted for ceilings, as when fixed to ceilings they prevent the spread of fire to the wood joists, while in the case of steel beams they resist the heat and prevent distortion.

It may further be mentioned that asbestos-cement roofing slates are made by the same firm, hydraulically pressed to ⅛ in. thick. These asbestos-cement slates are non-absorbent and practically indestructible, even in atmospheres charged with sulphurous fumes. They also possess very considerable mechanical strength, which is a most important characteristic for any material intended to be used for roofing purposes. The material being a mineral product is impervious to vermin, not liable to rot; and, being unequalled for insulating purposes, is not only highly recommended for buildings in which a regular temperature is required, but its electrical insulating properties make it very suitable for switchboard work.

Uralite is another asbestic product, being composed of asbestos-fibre cemented by a mineral glue. It is produced in the form of hard sheets for lining partitions and walls, forming ceilings, covering roofs, and for other purposes, including the construction of armoured fire-resisting doors.

Silicate cotton, or slag wool, blown into this form from molten blast-furnace slag is also a most valuable fire-resisting material. Being virtually a crude form of glass it is practically indestructible, and as its melting point is very high it is absolutely fireproof. This material is very generally supplied in combination with wire lathing or wire netting, and is then serviceable for filling the interior parts of partitions, but these require to be covered with sheets of non-combustible character to give the requisite finish. The usual practice of employing timber studding, and then covering boards, is clearly inadmissible from the point of view of fire-resistance.

Two systems of partition walls can be constructed with the Excelsior and Phœnix patent slabs. These are made up of a composition including pumice-stone, which has well-known fire-resisting and hygienic qualities.

These partitions, being solid, are therefore sound and vermin-proof. They are self-supporting, and are said to be about 50 per cent. lighter than brickwork. They are built upon the tongued and grooved plan, and are 3 ft. long by 1 ft. wide and

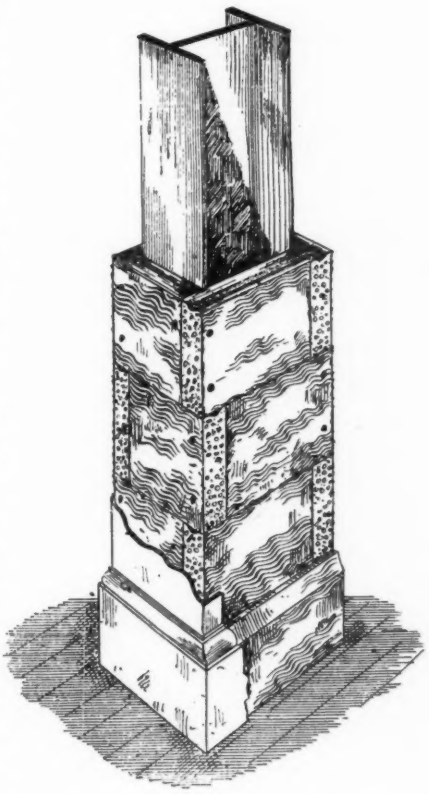


FIG. 15.—MACK'S PATENT SLABS: METHOD OF PROTECTING STEEL STANCHIONS.

vary in thickness from 2 ins. to 2½ ins., 2¾ ins., 3 ins., and 4 ins.

Not being a plaster-slab properly, it must not be wetted before the plastering process; the proprietors claim that

the slab in its dry condition takes any plaster; and that, as the composition of the slab prevents the quick absorption of moisture from the plaster coat, the latter has time to become a homogeneous cast with the slab. Therefore partitions of this material, properly plastered, should not blister.

The Company also manufacture ceiling slabs, 6 ft. by 1 ft. by $\frac{3}{4}$ in. and 1 in., which are applied to the ceiling joists or girders, and make a cheap and very good ceiling that does not crack. Slabs of this thickness are also used for lining wooden buildings, and for lining the inside of roofs of factory sheds, keeping the atmosphere within more even, as they are non-conductors of heat.

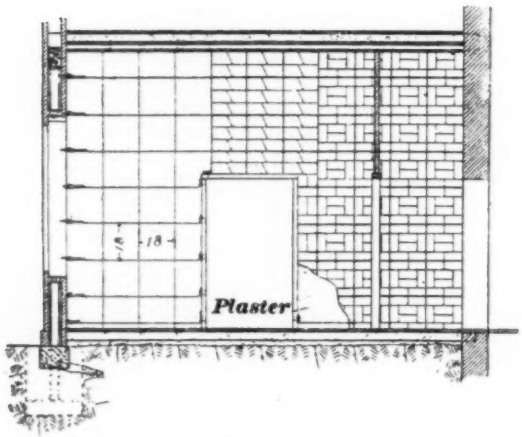


FIG. 16.—DETAIL OF FIREPROOF PARTITION—THE FIREPROOF PARTITION AND SPANDREL WALL CO.

Both partition and ceiling slabs can be spiked or nailed, and sawn to any required length.

Mack's patent slabs are made from specially prepared gypsum, having embedded strong hollow reeds of the nature of bamboo. The reeds form sealed air-chambers, and with plaster make a light non-conducting material of great strength, and their fire-resisting qualities have been proved by the official tests of the British Fire Prevention Committee. These slabs are very easily applied, and Fig. 15 shows one very useful manner in which they may be utilised for the protection of steel stanchions.

The self-supporting solid walls and fireproof partitions built by the Fireproof Partition and Spandrel Wall Co. consist of iron, brick, and cement, are erected so as to form one solid rigid plate; and the iron being embedded in cement is protected from the influence of fire and wet. The method of construction is shown in Fig. 16, where bricks of two different shapes are indicated. In erecting a partition, the position of same is first traced on the floor or beam, as the case may be. The door jambs are put up, the distances of the vertical hoop-irons are then suspended and tightened, after which the brickwork begins. The first horizontal hoop-iron is placed on the bottom course, firmly gripping the door posts.

The various materials to which we have briefly alluded may be applied to practically all structural parts of a building, from the foundations to the roof; and, by a judicious selection, it is perfectly in the power of a competent designer to render any new building reasonably secure against permanent injury by flame and heat.

The Baltimore and other great fires emphasise the lesson that it is of the utmost importance to prevent the flames from gaining access to the interior of any building, so that the fire-resisting construction shall not be subjected to unnecessarily severe exposure, and that inflammable fittings, furniture, and other property may be preserved. Armoured fire-doors and window-shutters and fire-resisting glazing are, therefore, most valuable aids to the fireproof engineers.

Ordinary steel-plate doors are of service up to a certain point, but they speedily succumb to fierce heat. Steel-sheathed

wooden doors constitute a further improvement, as they do not warp under the most severe heat, and by the exclusion of the atmosphere from the wood combustion is prevented. Such doors have repeatedly been brought into service in cases of actual fire, and have rarely, if ever, been known to fail. An armoured door of this type is made by Messrs. Mather & Platt, Ltd.

Another improvement is to be found in the adoption of Uralite sheets for the protection of timber doors. In the construction of uralite armoured fire-doors, sheets of uralite are fixed upon the outside faces of the woodwork, and the whole is then encased with tinned steel sheets.

(To be concluded.)

LIQUID AIR:

ITS PRODUCTION AND COMMERCIAL VALUE.

It has long been known to the students of science that gases could be liquefied, and it has equally been known to them that the means for liquefying them are high pressure or cooling them down to a low temperature. Such gases, for instance, as ammonia, sulphur dioxide, etc., are obtained in a liquid state by either method, and in 1834 Thirlorier liquefied carbon dioxide by high pressure at ordinary temperatures; in fact, a pressure of 50 atmospheres suffices for liquefying this gas at a temperature of about 13 degs. Cent. (55·40 degs. Fahr.). Hydrogen, oxygen, nitrogen, atmospheric air (which is a mixture of the two latter with slight additions of other gases) defied for a long time all attempts at liquefaction, and were called, therefore, non-coercible or permanent gases. For many years, especially after Natterer had failed to obtain a result at the enormous pressure of 2,790 atmospheres, the problem was considered insolvable; and yet all the time experimenters had been at the very threshold of its solution, for all that was needed was the simultaneous use of pressure and low temperature, instead of their separate use, and the continuation of their cooling down until the "critical" temperature of the gas to be experimented with had been reached, when the "critical" pressure would at once produce liquefaction. But until very recently the existence of these so-called "critical" conditions was not known, although as early as 1822 an experiment was performed by Cagniard de la Tour that might have given an indication of their existence. This experiment consisted in placing a liquid in a closed tube sealed at both ends, and heating it. By doing so, the French scientist discovered, that notwithstanding the pressure, when the temperature had reached a certain height, the surface of the liquid became gradually flatter, until the meniscus entirely disappeared, indicating that the surface tension was diminishing, while ultimately the space that had been filled by the air above and the liquid below, sharply divided from each other, assumed a perfectly homogeneous appearance, showing that the liquid had been changed into gas. This result contained indirectly the hint that at a definite temperature a gas can no longer exist in a liquid state, and that liquefaction begins only below this definite temperature, now called the "critical temperature." At the time, Cagniard de la Tour's discovery did not attract very wide attention, nor was he himself led to draw from his experiment the above conclusions. It was not until 33 years later, that Wolf and Drion repeated his method, and tried to ascertain for various liquids the temperatures at which, in a closed tube, the meniscus disappears. In the year 1861 Mendelejeff

also studied the question, and introduced the term "absolute boiling point" for these temperatures, which he defined as the temperature at which the cohesion of a liquid is zero, and at which such a liquid, regardless of pressure and volume, becomes a gas. Two years later, 1863, Dr. Andrews undertook his well-known classical series of experiments, in which he studied the relations between pressure, volume and temperature in the case of carbon-dioxide (CO_2), and ascertained that this gas above the temperature of 30·92 degs. Cent. (87·79 degs. Fahr.) can no longer be liquefied. He gave to this temperature the name of "critical" temperature, and to the pressure at which just below this temperature liquefaction occurs, the name of "critical pressure."

At present we know that every elastic liquid has its critical temperature, above which no liquefaction is possible; but to Andrews belongs the credit of having established the scientific basis of this knowledge. His work gave a new impulse to the experiments for liquefying gases, and, especially, Faraday devoted much thought to this problem, and was quite successful in liquefying numerous gases in a simple manner, of which his liquefaction of chlorine is typical. He placed the substances from which chlorine can be evolved into one end of a strong, bent glass tube, closed at both ends, while the other end of the tube was immersed in a freezing-mixture. The temperature of the freezing-mixture being below the critical temperature of chlorine, the pressure produced by the rapid evaporation sufficed to cause liquefaction. Hydrogen, oxygen, nitrogen, carbon-monoxide, etc., however, still defied all attempts to liquefy them, until Cailletet and Pictet in 1877 surprised the scientific world by announcing that they had succeeded in liquefying oxygen; which they followed up soon afterwards by the liquefaction of most of the other so-called permanent gases. Both combined high pressure with the cooling down to a very low temperature, and a short description of the method used by Pictet will suffice to explain their success. Pictet began by compressing sulphur-dioxide (*see* Diagram, Fig. 1) in a pump *A*, which then entered in a liquid form into the cooling-jacket *C D*, the vapour formed in the space above the liquid being pumped back into *A*. By this rapid evaporation of the liquid dioxide thus produced a temperature of about – 70 degs. Cent. (– 90 degs. Fahr.) was obtained in the jacket. The pump *B* was used to compress carbon-dioxide gas, which was liquefied in the tube passing through the midst of the sulphur-dioxide jacket. The liquid carbon-dioxide was then sent into the cooling jacket *E F*, where, by pumping the vapour there formed back into pump *B*, a temperature of – 130 degs. Cent. (– 202 degs. Fahr.) was obtained. For the production of the oxygen a quantity of potassium chlorate was heated in a strong vessel *V*, and the gas evolved was forced into a tube passing through the midst of the carbon-dioxide jacket. When the manometer *M* indicated a pressure of 500 atmospheres, liquefaction of the oxygen commenced; but on opening the top, to permit the liquid to flow out, a white jet was observed, the liquid oxygen immediately evaporating.

Notwithstanding their usefulness, however, for liquefying the so-called permanent gases, the methods used by Pictet and Cailletet were not well adapted for the study of the gases in their liquid condition, and for ascertaining definitely the constant, *i.e.*, absolute boiling point, critical temperature, volume, etc. The first to do this was Wroblewski, whose researches were of the highest scientific accuracy; and, after him, the work was continued with great success by Olszewski, Dewar, Hampson, and Professor Linde. It was the latter who discovered the most practical method for liquefying air which we shall describe presently.

The technical obstacles to be met with are to be found not so much in obtaining high pressures, but rather in reducing the gases to the critical temperatures, which, in most cases, are very low, and could evidently not be secured by the ordinary freezing mixtures, excepting the incidental use of the latter in a very few cases. The methods for obtaining such temperatures are, in nearly every case, based upon the physical law according to which a

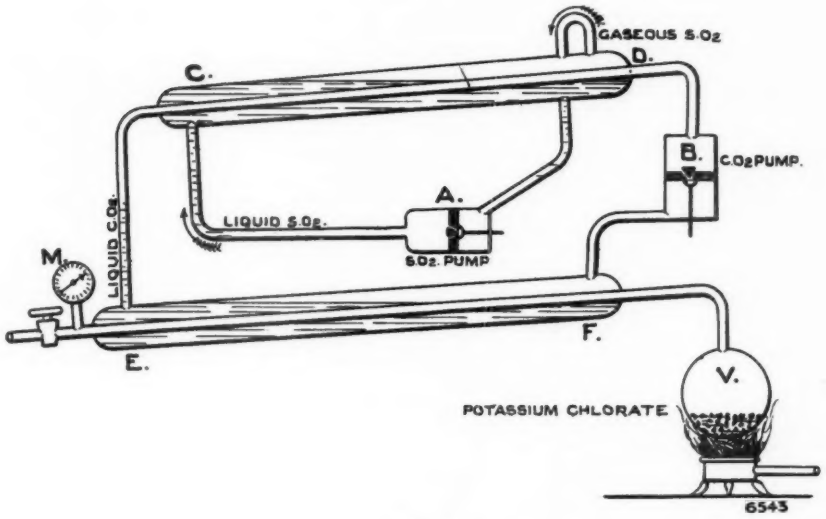


FIG. 1.

substance in order to change from the liquid to the gaseous state, requires a certain quantity of heat, which, unless it is furnished from the outside, has to be taken from the substance itself that is undergoing the change. Thus heat becomes, therefore, tied up, so to say, and a fall of temperature is the result.* Upon the application of this law rest the experiments of Pictet and Cailletet above described.

A further illustration of this is furnished by the various systems of refrigerators now-a-days used, which may be divided into absorption and compression systems. The former system is represented for instance by the ammonia refrigerator of Carré. In one form of this refrigerator an aqueous solution of ammonia is first heated to about 130 degs. Cent. (266 Fahr.) in a strong iron vessel *A* (Fig. 2), the ammonia vapour which is expelled being condensed in the space between the double walls of the vessel *D* which is surrounded by water. After a sufficient quantity of ammonia has been distilled over in this manner, the vessel *A* is cooled by being surrounded with water. When the temperature in *A* has been sufficiently reduced the ammonia evaporates from the vessel *D*, which consequently falls in temperature, and water that has been previously placed in *E*, the central cylinder of *D*, is thereby frozen. The compression system forms the basis of the ammonia refrigerator constructed by Professor Linde. In this refrigerator, represented diagrammatically in Fig. 3, the piston *K*, in the cylinder *C*, moved by a steam engine, serves to compress the ammonia vapour which enters into it from a vessel *V*, to the left, where it is produced from an aqueous solution of ammonia by the heat of a spiral *D*, through which steam passes A stop-cock *h* is turned to prevent the further flow of the vapour when the steam is shut off. By moving to the left, the piston *K* compresses the ammonia vapour to a pressure of 12 atmospheres. This suffices to liquefy a portion of the ammonia; which, together with the remaining vapour, passes into the condenser *R*, where it descends through the interior spiral, which is kept cool by a constant flow of water at ordinary temperature; and here the

* And *vice versâ*, when a gas is compressed heat becomes free.

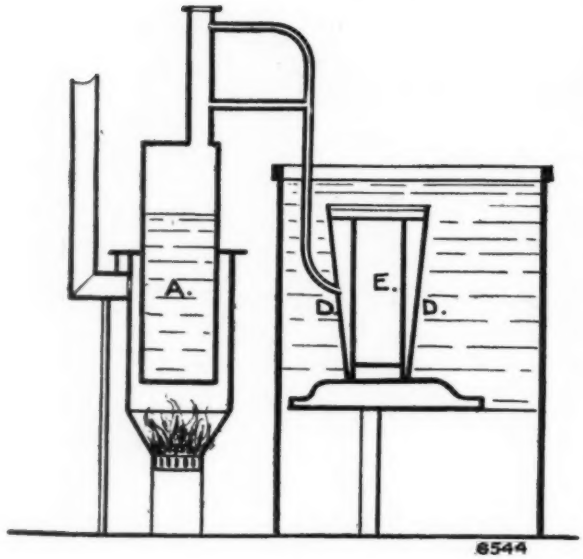


FIG. 2.

remaining ammonia vapour, which of course is still under pressure, also becomes liquid. The liquefied ammonia then passes through a tube enveloped by non-conductors of heat into the evaporators, a cylinder having a height of about 4 ins. and a diameter of about 3 ins. in the axis of which a vertical rod furnished with horizontal arms is kept in rotation. The tube enters this cylinder at the top, passes vertically downwards for a few inches, when it assumes a horizontal position, and from this horizontal position radiate a number of branch-tubes, which, in spiral windings, pass downward through the cylinder. (In Fig. 3, there is shown one spiral only, to indicate the direction of the windings, but in reality there are many intertwining tubes.) When the liquid ammonia leaves the tube by which it entered, and passes over into the system of tubes, it expands into a larger area, represented by the sum of the cross-sections of the branch tubes, and consequently is changed again into vapour. Since this vaporisation takes place without the aid of external heat, the temperature of the ammonia itself is lowered, and this low temperature is communicated to the solution of salt, or of calcium chloride, surrounding the spiral, and as such a solution does not freeze at the temperature produced, it may be led off at *T* for the manufacture of ice, for cooling cellars or for other refrigerating purposes. The ammonia vapour afterwards passes back again to the pump *C*, through the tube *U*, and is once more condensed by the next stroke of the piston, and the whole process is repeated as long as may be desired.

Another physical law meanwhile began to occupy the attention of some of the experimenters who aimed at a practical method for liquefying the permanent gases, namely, the law that in all heat engines heat disappears when work is performed, and that the quantity of heat disappearing is mechanically equivalent to the quantity of work performed. Cailletet also had considered the question whether it might not be possible to obtain a further reduction of temperature by letting the highly compressed gas escape from a small opening, and employ it in moving a piston in a cylinder. As early as 1857 Sir William Siemens proposed the combination of a "regenerator" or temperature converter with an expansion cylinder, in order to communicate the resulting fall in temperature to the surrounding air; and thus to obtain, as he said, a constantly increasing effect or an unlimited reduction of temperature. Only recently this idea was put into practice by Solvay and Windhausen, who patented a process based upon it, and by Professor Ohnes in his cryogenic laboratory at Leyden; all of whom employed a cylinder in which the expanding air was reduced in temperature by performing work. Soon, however, it was found that there arose serious obstacles

to the practical realisation of the theory, *i.e.*, to the "unlimited reduction of temperature" by the means mentioned by Siemens, and Solvay discovered that – 95 degs. Cent. (– 139 degs. Fahr.) was the lowest temperature obtainable in this way, for not only are the mechanical difficulties for operating a piston at a very low temperature very great, but the friction caused by its motion in the cylinder serves as a conductor of heat from the outside in sufficient quantities to prevent the reduction of temperature beyond this limit. It was not before Dr. Linde had put into practice a new method that it really became possible to obtain a constantly increasing effect in lowering the temperature of an expanding gas. This method was based on the idea that a great reduction of temperature might be obtained by permitting gas under very high pressure to escape through a very fine opening, as, for instance, through an almost entirely closed throttle-valve, into a larger space; and this idea he applied to the reduction of the temperature of air. All other methods by which, as mentioned above, a liquefaction of the permanent gases had been obtained, were too complicated and too expensive to be of commercial value. By Dr. Linde's method, as we will see, liquid air can be obtained at about a penny a pound; though its practical value for refrigeration, for reasons afterwards to be mentioned, is far below that of the methods hitherto in use, and though not any of the extravagant claims put forward by the liquid-air companies has ever been verified.

The idea that by the expansion of a gas, even if no external work be performed, still some internal work might be performed, *i.e.*, the work required for overcoming the attractions exercised by the molecules upon each other, had occurred also to Joule many years previously. If such should be the case, he reasoned, it would be indicated also by a fall in temperature upon the compressed gas passing through a small opening and expanding into a larger space. An experiment made by him for verifying this, however, failed to show any fall of temperature, and he concluded that the wider separation of the molecules exercised at least no appreciable effect. At a later period, however, he realised that his experiment might not have been accurate

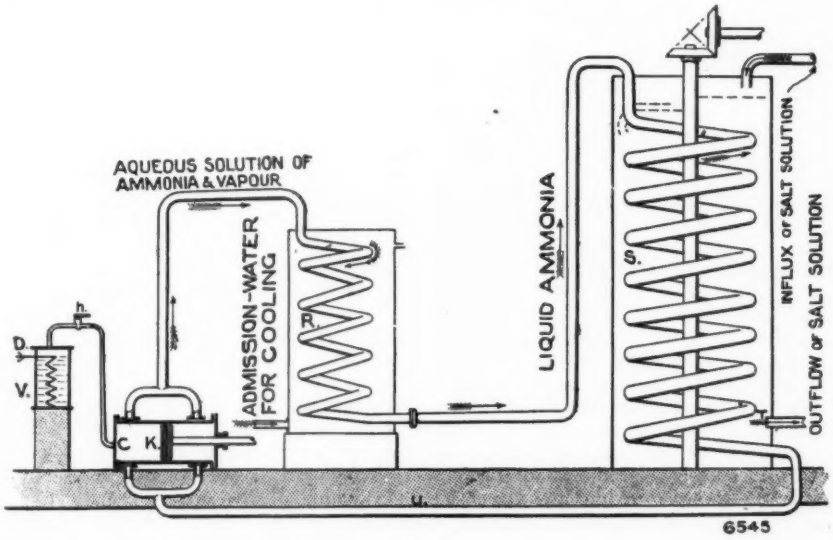


FIG. 3.

enough; and upon renewing his inquiry together with Lord Kelvin, under more scientific conditions, it was ascertained that the gas upon expansion really did slightly fall in temperature—the fall in the case of air at normal temperatures amounting to about ¼ deg. Cent. (0·45 degs. Fahr.) for each atmosphere by which the pressure was reduced. In all cases the thermal effect was proportional to the difference between the pressures before expansion and after expansion, though at high temperatures the effect was less than at low temperatures. Its actual magnitude varied inversely as the square of the *absolute* temperature of the gas.

The drop in temperature by ¼ deg. Cent. for each atmosphere of difference of pressure may in itself appear too small to be of practical value; but Dr. Linde recognised, that since the effect is the greater the lower the temperature is at which the expansion takes place, the reduction can be rendered continuous by utilising the first quantity of air that, after compression, has been reduced by a few degrees only, upon passing through a small orifice into an under area, for cooling the next quantity of compressed air, subjected to the same conditions. This second quantity being of a lower temperature at the beginning of expansion than the first quantity, according to the law above stated, falls in temperature to a far greater degree, and so on, until the degree for liquefaction should have been reached. This method of reasoning he put into practice, and without much difficulty he obtained a temperature of – 200 degs. Cent. The apparatus at first employed by him is shown schematically in Fig. 4.

The pump *P* forces highly compressed air, by way of the tube, *H J B*, through the water cooler *K L*. The heat generated during the compression is thus removed. The compressed air then passes along the tube *C B*, which is in direct connection with the inner spiral tube of the "interchanger" *C D E*. The compressed air finally escapes through the small opening of the throttle-valve *R* into the vessel *T*. At this point a fall in temperature takes place and the cooled air passes through the space between the inner and outer spiral tube of the interchanger and the tube *C G* back to the pump *P*. Thus the air now approaching the throttle-valve is at a lower temperature, and since this process is repeated with every stroke of the pump, the air grows colder and colder, until liquefaction occurs. In May 1895, Dr. Linde, by using this apparatus based on producing a "constantly increasing effect" of refrigeration, obtained, after the pump had been working for fifteen hours, liquid air without any previous cooling of the air by other methods, and by a system entirely differing from that by which Pictet, Dewar and others had succeeded in liquefying the permanent gasses.

Further, Prof. Linde constructed on the same principle a far more elaborate and effective apparatus illustrated schematically in Fig. 5.

The compressor used is a Whitehead two-stage air-compressor with cooling jackets. This air-pump delivers air from the high-pressure cylinder *c* at 200 atmospheres by way of the tube *p* (a strong copper pipe of 0·4 in. diameter) to the water separator *d* (provided with the pressure-gauge *g*), where the air is dried, thence to the carbon-dioxide separator *f* filled with soda-lime, through which it ascends, and then descends through another pipe into a spiral iron pipe of 1 in. diameter, enclosed in a box *e* containing a freezing mixture of salt and ice. Then the last traces of moisture are removed by its freezing against the inner wall of this pipe, and the air pure and dry is now forced upward through the pipe *p'*, into the inner tube of a very long spiral, consisting of three concentric tubes, of the interchanger, where it descends until it reaches the throttle-valve *m*, where, through a pinhole opening, it passes into the space between the inner and the second tube, the pressure thereby being reduced to 16 atmospheres. About one-fifth of this air subsequently passes through the throttle-valve *n*, where, escaping through another pinhole opening, it is reduced to a little more than one atmosphere, a part (about one-quarter) becoming liquid while the remainder moves upward through the space between the second tube and the inner wall of the

outside tube, escaping to the open air at p'''. The other four-fifths of the air at 16 atmospheres pressure passes upward through the space between the central and the second tube of the spiral, cooling the air now ascending through the central tube; and, while a portion branches off at the left to the manometer *H*, to register the reduced pressure, the bulk passes down the tube p'' to the high-pressure cylinder *c*, where it meets air also at 16 atmospheres coming from the low-pressure cylinder *b*. In this cylinder air coming from the outside is compressed to that density; on leaving it passes through a spiral surrounding the cylinder and, immerged with it in cool water, which flows through the iron casing in which the cylinder is enclosed, is forced over into the high-pressure cylinder through tube p'', and is compressed to 200 atmospheres; the heat caused by the compression is removed in the cooling jacket surrounding cylinder *c*, and the process is repeated.* In this way liquefaction takes place first in a smaller and gradually in larger quantities, and the liquid is collected in a heavy Dewar flask *o*† underneath the apparatus.

The power required for the compressor is about 3 h.p. (in the laboratory of Michigan University a 5 h.p. electric motor is used), and the machine begins to supply liquid air after from 30 minutes to two hours, furnishing 0·15 cub. m.[3] per minute.

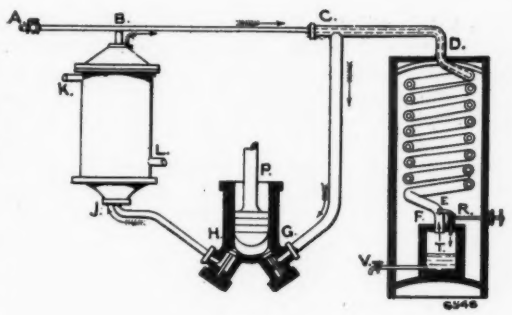


FIG. 4.

The apparatus described puts into constant circulation about 15 cub. m. of air at a pressure varying from 200 to 16 atmospheres, and about 3 cub. m. per hour are pumped in from the outside to replace the liquefied portion.

The type of liquefier described is con-

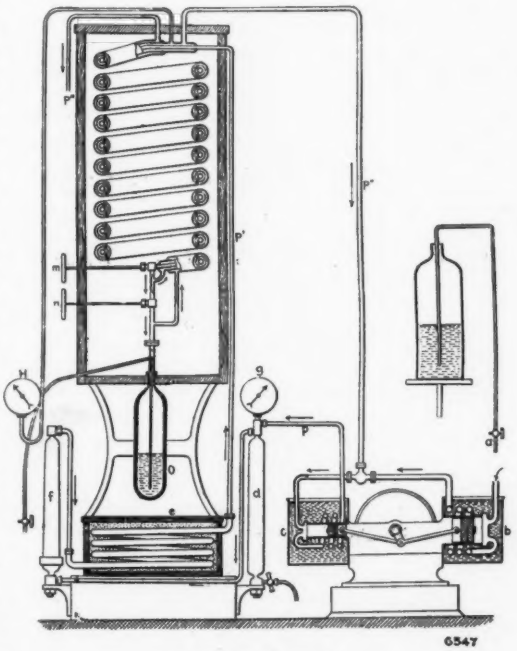


FIG. 5.

* The low-pressure cylinder is about 3 ins. in diameter, and the high-pressure 1¼ in., the stroke being 2 ins. in each case. All internal parts of the compressor are lubricated by distilled water, dropped from a tube *a*. This water is removed in the water separator *d* as described, and in the spiral enclosed in the freezing mixture. Oil cannot be used for lubrication, as it would be too difficult to remove from the air.

† A Dewar flask is a glass flask having double walls, between which a vacuum is caused by exhausting the air, and this vacuum reduces the conductivity of the vessel for heat from the outside to a minimum, especially as there remains a trace of mercury after the exhaustion of the air, which is condensed into a mirror on the walls of the vessel, thus further diminishing the radiation.

structed in various sizes, requiring 5 and 7 h.p. respectively, which are in use in many Continental laboratories.

Modifications of Professor Linde's apparatus have been devised by Professor Dewar and Dr. W. Hampson. In the year 1896 the latter announced the invention of a liquid-air apparatus, which is easily recognised as a reproduction of Professsor Linde's liquefier in almost unaltered form. Dr. Hampson's apparatus is far smaller and lighter than Professor Linde's, and can be easily carried by one man, but it consists merely of the interchanger with the throttle valve and the collecting flask, leaving the owner to secure his compressed air as best he can, while in Professor Linde's apparatus the air compressor forms an integral portion. Fig. 6 shows schematically the construction of Dr. Hampson's liquefier. Air at a pressure of 200 atmospheres enters into the cylinder *c*, at the right hand of the figure, which is filled with caustic potash to remove carbon dioxide, escapes through the upper portion, a small quantity branching off to register the pressure at the manometer *M*, and after passing through numerous spiral windings in the interchanger reaches the throttle valve *A*, which is manipulated at the top by turning a little bar *B*, and by expanding liquefies in a small quantity, which collects in the vacuum vessel *C*, while the non-liquefied portion passes into the cylinder surrounding the spiral tubes, after cooling which it escapes into the open. The vacuum vessel *C* is surrounded by a number of glass cylinders which, by means of the strata of air enclosed, are intended to act as non-conductors, and the liquefied air can either be drawn off at *E* or the vacuum vessel can be lifted out. The efficiency of the apparatus can be increased, it is stated, by permitting liquid carbonic acid to enter at *F*, and to circulate in the space between the spiral and the surrounding cylinder. The temperature of the entering and escaping air is measured by the thermometers seen on top of the apparatus.

In March, 1898, Dr. Hampson published in *Engineering* a table in which he tried to demonstrate the superiority of his apparatus over that invented by Professor Linde. The data given refer to reduction of size, weight, higher effect and diminution of labour. The Linde Refrigerator Company in Munich, however, contradicted the correctness of these data emphatically in the *Zeitschrift für die Kälteindustrie, Vol. VI., No. 2, Feb. 1899*, and declared them to be derived from totally wrong premises. Without entering upon a discussion or a criticism of the controversy it may be merely stated that Hampson declared that his apparatus begins to liquefy air about 16 mins. after starting and supplies 1·2 litre per hour. To this Professor Linde replied that, in all apparatus with a single cycle, such as those of Dewar or Hampson, the time required for the first signs of liquefaction is about the same as in his own liquefiers with double cycle; that, however, for every additional litre of liquid air, his own liquefiers require at the highest about one-third of the labour needed for the Dewar or Hampson liquefiers.

Unless the carbonic acid accompanying the air into the tubes is removed (as is not done in the liquefiers of the older type), the liquefied air has a milky appearance, caused by particles of solidified carbonic acid; which, moreover, is apt to obstruct the free flow of the air through the pipes. These solid carbonic acid particles, resembling snow, can be removed by filtering the liquid air through ordinary filter paper or cotton-wool, when it can be collected as a clear, transparent liquid of a bluish cast.

The preservation of liquid air, even for very short periods of time, is extremely difficult. It cannot be kept in closed vessels like liquid of carbon dioxide for instance, which is transported in strong steel flasks, for the pressure upon evaporating is so enormous that it would be necessary to construct very bulky and heavy receptacles to contain even the smallest quantities. The only way to keep it and transport it is in open vessels surrounded by a vacuum-jacket of the Dewar flask type, which are such excellent non-conductors as to reduce the heat communicated to the liquid from outside to $\frac{1}{33}$, or to about 3 per cent. Kept in such flasks,

provided the latter are wrapped in material which is a bad conductor of heat, such as wool for instance, and are left open, or are closed merely by a porous stopper, so as to allow the vapour to escape, the liquid air may be kept for a short period, and under favourable conditions a few days may pass before all of it is evaporated.

A very important feature, referring to the preservation of liquid air, must now be mentioned, namely, its fractional evaporation—*i.e.*, the evaporation of its constituents one before the other, which changes the character of the remaining liquid as regards the proportion of its elements. When air is liquefied both the nitrogen and oxygen liquefy together; but Dewar observed that when the liquid air evaporates, the nitrogen evaporates more quickly than the oxygen, and at a temperature which is 13 degs. Cent. lower than the boiling-point of oxygen; consequently the remaining liquid becomes richer and richer in oxygen the longer the evaporation has lasted. Thus, for instance, after 70 per cent. of the liquid air has evaporated, the remaining 30 per cent. of liquid contains not, as atmospheric air does, 20 per cent., but 50 per cent. of oxygen. Professor Linde, utilising this peculiarity, has constructed an apparatus furnishing an air-current very rich in oxygen, and this apparatus is employed in the chemical works of the Rhenania Company at Aix-la-Chapelle, in connection with the manufacture of chlorine by the Deacon process. The high percentage of oxygen in liquid air furnishes lecturers on the subject an opportunity for a number of very effective combustion experiments; which, however, do not add much to our knowledge of its nature, and may therefore be left undescribed. The scientific value of liquid air lies mainly in its use for obtaining very low temperatures. Pictet had already made researches regarding the effect of such temperatures upon chemical reaction, and had concluded that this ceases entirely at the very lowest temperatures, a conclusion which was corroborated by Professor Dewar's experiments. The faculty of a body of forming a chemical combination with another body at very low temperatures,

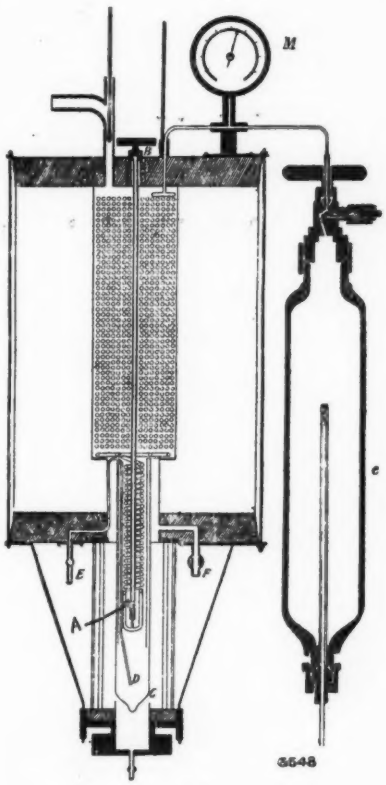


FIG. 6.

either altogether disappears or is reduced to a minimum; thus, for instance, hydrochloric acid and metallic sodium, which at an ordinary temperature combine with luminous effect, do not react at all upon each other, or very little only, when brought together at very low temperatures. It is notable, however, that chemical reactions, which at ordinary temperatures occur without signs of great energy, as for instance the reddening of litmus-paper by acids, are still perceptible at even very low temperatures; and Dr. Spies has shown that photographic plates continue to receive impressions, though not very readily, at a temperature as low as that of liquid air. On the other hand the mobility of

the molecules of a body is considerably reduced even at temperatures not lower than – 100 degs. Cent. Soft bodies, such as a piece of india-rubber tubing, after immersion in liquid air, become so hard that they can be crushed into small fragments by a blow with a hammer; and flower blossoms become so brittle that they can be reduced to dust; while soft metals, such as lead, become so hard that a leaden ball after being cooled to a very low temperature emits a metallic sound.

Liquid air has also enabled the scientist to make new discoveries regarding electric resistance. Professors Dewar and Fleming have made the interesting announcement that the resistance of pure metals decreases the more the absolute zero (– 273 degs. Cent.) is approached, which renders it probable that at absolute zero such metals are perfect conductors of electricity. As regards magnetism, it has been known from the experiments of Plucker and Faraday that oxygen is attracted by very powerful magnets; it has now been found also that if a Dewar flask containing liquid air is placed between the poles of an electro-magnet and the electric circuit is closed, the liquid rises at the two sides of the flask near the poles, and if it is brought near the poles in a shallow dish a little fountain is formed. Finally, if other liquid is poured through a narrow opening between the poles, the liquid column is stopped by the magnet and descends only after the circuit is opened again. Another phenomenon discovered by Professor Dewar is that many substances, alter being immersed in liquid air and then being exposed for a few moments to sunlight or electric arc-light, become phosphorescent on being placed in a dark room. Thus phosphorescence has been shown in the case of india-rubber, asbestos, wood, egg-shells, leather, and many other substances; cotton-wool emits a beautiful greenish light, frozen coal-oil a bluish light; and, in fact, from the experiments of Dr. Spies it appears that, excepting the metals, there seems to be hardly any substance that shows no phosphorescence when cooled down to a low temperature and submitted afterwards to light.

Among the important scientific discoveries connected with liquid air, must not be omitted that of some new constituents of air. ***Krypton*** was discovered by Professor Ramsay and Dr. Travers by allowing a quantity of liquid air to slowly evaporate, and examining the spectrum of the last traces of gas given off. When the first and last traces of gas given off during the slow evaporation of argon were examined, two new gases, to which the names of ***neon*** and ***meteuzon*** have been respectively given, were found to exist.

Lastly, amongst the characteristics of liquid air may be mentioned, that if it is mixed with charcoal, naphtha, etc., an explosive is formed. A most effective compound of this kind is obtained by combining marl and naphtha with liquid air, which has been named *oxyliquit* by Dr. Linde.

We now come to the question of the *technical* and *commercial value* of liquefied air.

The best results obtained up to the present in attempts for preserving liquid air in metal receptacles—the expensive and fragile Dewar flasks being of no practical value where the transport of large quantities of the liquid is concerned—showed a loss of 2 kg. per hour, out of 50 litres contained in a metal flask, *i.e.*, a loss equivalent to 7 per cent. Speaking of the value of liquid air for refrigerating purposes Dr. Linde, at the seventy-first meeting of German Naturalists and Physicians at Munich, September 17 to 22, 1899, said: "I regret that I cannot emphasise it too much and explain it loud enough for everybody to hear it: ***a rational method for refrigeration by liquid air does not exist.***"

Liquid air at *2d.* per kilogramme, *i.e.*, about *1d.* per lb., is certainly cheap compared with what it would have been if prepared by the methods in use before that invented by Dr. Linde; but since from 1 kilogramme not more than about 125 calories are obtained, no cold storage engineer would even for a moment think of using this substance for refrigeration; in reality liquid air is about 25 times as expensive for that purpose as ammonia.

Still less economical is its use for

motors on account of the many technical obstacles in the way, as well as on account of its physical characteristics which make it impossible to obtain in the form of work more than about 4 per cent. of the power required for its compression.

Although liquid air is useless for refrigeration on a commercial scale, and for motor power, except in cases where the expense may be ignored, as for instance in connection with motors for torpedoes or other military appliances, where efficiency is the sole consideration, there are still many fields, however, in which its practical usefulness deserves to be or is being tried. Among them we may mention the cooling of the air in mines. Mr. Louis Fübben, of Dortmund, Germany, appears to have obtained a patent for this purpose. In the specifications he points out that since 1 litre of liquid air by being heated to a temperature of 20 degs. Cent. (68 Fahr.) is able to withdraw about 120 calories from its surroundings, it suffices for cooling 30 m^3 (1059·30 cubic feet) from a temperature of 20 degs. Cent. (68 Fahr.) to 10 degs. Cent. (50 Fahr.). And of even more value might be the use of liquid air for purifying fuel air in mines, or rather for raising the percentage of oxygen in such air. This might be of practical use in those subterranean galleries where the usual methods would be so expensive that liquid air, notwithstanding its high price, would be the most economical.

Another field in which the use of liquid air has already given fairly promising results is that of explosives, mentioned already. The first experiments with liquid air for blasting purposes were made at Pewzberg (Upper Bavaria), when liquid air mixed with powdered charcoal was used, and further experiments have been in progress for some time in the Simplon Tunnel. The results seem to show that Dr. Linde's oxyliquit is more effective, pound by pound, than nitro-gelatine though, volume per volume, the latter gives better results.*

Similar experiments were also made near Vienna by the engineer Karl Heimpel, the representative in that city of the Linde Ice Company. These experiments were witnessed by several members of the Technical Commission of the Imperial Austrian War Office, and by an expert of the Vienna Police. The scene of operation were the quarries of E. Gross & Co., at Ober-Sievering, and the liquid air was sent from Munich. During the transport and the time intervening between its arrival and the moment of its use, *i.e.* during a period of 72 hours, about 50 per cent. of the liquid air had disappeared. The air manufactured in Munich for blasting purposes was stated to contain originally about 75 per cent. of oxygen and 25 per cent. of nitrogen, so that at the time of its use it may be assumed to have represented a mixture of about 85 per cent. of oxygen and 15 per cent. of nitrogen. The method employed was as follows : A fairly homogeneous mixture of silicious marl (Kieselzuhr) and "solar oil," was prepared in a wooden vessel. Into one portion of this, liquid air was poured, and the whole mass stirred until a stiff paste had been obtained for filling the paper cartridge shells, covered with asbestos. The other portion of the marl and "solar oil" mixture was put, before the liquid air was added, into the cartridge shells, which were enclosed in a casing of tin with a layer of felt between, and the liquid air was then poured into them until the mixture was thoroughly saturated. These cartridge-fillings, therefore, contained liquid air of a rather uncertain per centage of oxygen and nitrogen. The fuses, containing 2 grammes of fulminating mercury, although 0·5 grammes it is said would have been sufficient, were merely inserted into the cartridges, and the latter placed in the bottom of deep holes bored into the rock. These preparations consumed about 10 minutes. The holes bored, three in number, had a diameter of 40 mm., and a depth of from 70—80 cm. For the first blast, two cartridges were used, which when completed weighed about 170 grammes, and after being firmly placed, they were ignited by electricity. In the first instance the electric spark failed to ignite the cartridges, probably because the conducting wire had

* *Ztshrft. d. ges. Kohlensaure-Industrie.*

slipped out of the cartridge, not having been carefully inserted. A new cartridge then was placed on top of the two others, and this time explosion took place, throwing up several cubic metres of rock. The two other experiments also were successful, but the opinion of the experts was that the cartridges were less effective than those filled with gun-cotton, nitro-gelatine, dynamite, or giant powder. The advantages of the new explosive were stated to be that it is possible to proceed to the scene of blasting immediately after the explosion; that, owing to the fact that the mixture becomes harmless after from 10 to 15 minutes, "oxyliquit" will not be likely to be misused for criminal purposes, and that when ignition has failed, it is quite safe after the lapse of about a quarter of an hour to withdraw the cartridges. The drawbacks, on the other hand, are the varying and uncertain strength of the explosive mixture and its rapid deterioration, which requires that it must be used without delay. Until these drawbacks are removed, liquid air will have but a very limited application for blasting purposes, though in special cases the compounds containing it may be preferable to more permanent explosives.

One more use of liquid air may be mentioned in conclusion, namely, its employment for the medical and hygienic treatment of disease. It is being tried in the treatment of lupus and cancer, and also for creating a pure and dry atmosphere, rich in oxygen, which ought to be of great advantage for persons suffering from asthma or consumption, since such air would be free from bacteria. All this, however, remains for the time being hypothetical; for the present at least the liquefaction of air is merely a triumph of scientific research, enabling us to study the effects of temperatures which were formerly unobtainable.

BOOK REVIEWS.

Electric Waves : Being an Adams Prize Essay in the University of Cambridge.—By H. M. Macdonald, M.A., F.R.S., Fellow of Clare College, Cambridge. 1902. (Cambridge: at the University Press.) 10*s*.

The Adams Prize at the University of Cambridge has always been regarded as the great and final honour in mathematics or science which a member of the University may hope to win. It stands apart from the Tripos or the Smith's Prize Examinations, which are tackled while the student is still a youth, and forms a test of the value of the work of the mature man. On previous occasions this contest has produced many worthy additions to mathematical and scientific literature—as, *e.g.* Prof. J. J. Thompson's work on "Vortex Rings"—and the University is to be heartily congratulated on the fact that the latest competition should have led to the appearance of two such noteworthy books as Professor Larmor's "Æther and Matter," and the volume now before us. Mr. Macdonald's essay is devoted to a discussion of "the possibility of obtaining directly from Faraday's laws a consistent scheme for the representation of electrical phenomena, and of applying the results to obtain the quantitative relations which exist in certain cases of the propagation of electrical effects." The most important part of the purely analytical portion of the work is that in which the author examines Maxwell's theory, and shows that while Maxwell gave it in two forms, in one of which the electro-kinetic energy is expressed in terms of currents, and in the other in terms of magnetic force and induction, only the first form follows logically from Faraday's laws. Maxwell himself did not use the second form to obtain results, but later writers have done so, and it is therefore necessary to examine the assumptions which have been adopted in its use. This has been done by Mr. Macdonald, who shows that many of the current ideas as to the nature of the æther—*e.g.* the assumption that Maxwell's electro-magnetic theory is the same as MacCullagh's optical theory, the identification of the magnetic induction as the velocity of the æther, and the assumption of an indefinitely great density of the æther—have all arisen from the use of Maxwell's second, and illegitimate, expression for the electro-kinetic energy, and that they are therefore not a necessary consequence of Maxwell's theory. When the general theory has been completed, and it has been shown that the Faraday-Maxwell theory is consistent with dynamical theory, and gives a consistent account of electrical phenomena, the author proceeds to apply his theory to some problems connected with the propagation of electrical effects, pointing out an essential difference (in respect of such propagation) between a simply-connected and a multiply-connected space, in that the former has no permanent free oscillations such as would not be dissipated by radiation ; while such oscillations are to be found associated with each of the conducting circuits in a multiply-connected region. By recognising this difference, the author is enabled to simplify the mathematical theory considerably. The principal application of the theory is to the effects observed and investigated by Hertz, and leads to theoretical results which are in close accordance with the observations of Sarasin and De la Rive, and which explain some of the discrepancies in Hertz's own observations. The work is highly analytical, but to mathematical readers it will appeal alike by the clear treatment of the subject and by the valuable results obtained by the author. Of the Appendices, special mention should be made of that on "The Relation of Theoretical to Experimental Physics."

Refuse Disposal and Power Production. — By W. Francis Goodrich, A.I.Mech.E., A.R.I.P.H. With 98 illustrations. (Westminster: Archibald Constable & Co., Ltd. 1904. 16*s*. net.)

During the brief interval which has elapsed since the publication of a previous work by the same author on "The Economic Disposal of Towns' Refuse," a new development has been evidenced in the practice of refuse destruction by the extensive application of waste furnace-gases from the cells to the purpose of power production. Hence it happens that municipal authorities

generally find two subjects for discussion when proposals are made for the introduction of refuse-destroying plant: (1) the desirability of getting rid of offensive matter in an inoffensive manner, and (2) the question whether the proposed installation will pay for itself in other directions. No doubt there are sufficient arguments in favour of refuse destruction from a sanitary point of view, without the inducement of commercial advantages. But as such extraneous benefits may frequently be, and often are, experienced by municipal corporations as a reward for their efforts in the cause of sanitation, there is every reason why the facts should be made generally known. In the work before us, Mr. Goodrich gives a comprehensive review of the whole subject. His qualifications to deal with it are already known to many of our readers, and although directly interested in one well-known firm of destructor makers, he has very carefully avoided any invidious comparisons, and in discussing several matters of highly controversial character has dealt with principles rather than with individual types of design and manufacture. The utility of the work is much enhanced by the large amount of information given in the form of records of tests, and actual working results furnished by various municipal engineers in this and other countries. The compilation of these data has evidently involved much labour, for which, however, the author should find himself amply repaid by the recognition of his treatise as a standard work on the subject.—*T.*

The Shipbuilding Industry of Germany. By G. Lehmann Felskowski. Quarto, 10*s.* 6*d.* net. (London: Crosby Lockwood & Son, 7, Stationers' Hall Court, E.C.; R. Boll, Berlin, N.W.

The strenuous endeavours to overcome the great difficulties in competing with England as a shipbuilding nation are set forth in an extremely graphic manner. It was in warship building that builders were enabled to accustom themselves to a durable and well-finished class of work. Merchant shipbuilding was at the outset severely handicapped on account of many of the German shipbuilders' business connections being so firmly rooted in English shipyards, cost of materials was much higher, nor was the plant sufficient for a quick and rational system of shipbuilding. Further, difficulties in connection with boiler-making, and the defects exhibited in the boilers made, caused German shipowners to have doubts as to the advisability of ordering steamers in Germany. Gradually these were overcome until, in 1887, the Hamburg-American line, by ordering the *Rugia* from the Stettin Vulcan and the *Rhaetia* from the Reiherstieg yard in Hamburg, started the building of large steamers in Germany. Since then, in the face of many difficulties, financial losses, and severe competition, of which only experience could prove of any effect, the growth of German shipbuilding has steadily advanced, until such vessels as the *Kaiser Wilhelm der Grosse*, *Deutschland*, and many others equally well known, have proved that Germany has entered the list as a serious competitor for the world's shipbuilding.

Some of the most striking features to be noted are the readiness with which labour-saving devices were and are adopted from time to time, the establishment of kindred industries in order to make shipbuilders independent of outside aid, the extreme care with which all the plant in shipyards and engineering shops is arranged so as to ensure a quick and economical execution of contracts, and the manner in which many of the large employers regard the welfare of their employés.

The book is an abstract of two works by another author—one on German shipbuilding and the other on the iron industry in relation to shipbuilding. The second portion deals seriatim with all the more important German shipyards; then follow sections on the iron industry in relation to shipbuilding, ships' equipment and armament, mechanical hoisting apparatus, and, finally, with German submarine cables. Each portion is most profusely and elaborately illustrated.

We can thoroughly commend the book to all those in any way connected with shipbuilding or owning, ordnance manufacture, steel-making, etc.; it will prove of immense interest and instruction. It is a work which will serve to bring home to our own manufacturers the determined efforts and up-to-date methods adopted in Germany to capture the lion's share of the world's shipbuilding.

Heating by Hot Water, Ventilation, and Hot Water Supply. Third Edition. By Walter Jones, M.I.Mech.E., M.I.H.V.E. 142 illustrations. (London: Crosby Lockwood & Son. 1904.) Price 6*s.* net.

Until the appearance of this work there was a distinct dearth of technical literature in this country dealing with the important subjects of heating and ventilation. Several excellent works on the same subject have been published in the United States, and we are pleased to welcome a similar treatise from the pen of a British engineer who has devoted himself to various departments of heating practice. In the volume now before us the author gives many suggestions and

much useful information as to the methods most suitable for heating and ventilating public, private, and horticultural buildings, by the high-pressure and low-pressure hot-water systems; he describes failures and how to prevent them, independent boilers, duplicate boilers, and gas boilers, radiators, laundry drying-rooms, Turkish baths, swimming baths, and improved methods of hot-water supply, and the cause and prevention of boiler explosions. Some parts of the treatment may perhaps be thought a little too elementary in character, but we have no hesitation in saying that the hot-water engineer will find in this book practically everything required for his information upon the details of everyday practice. The volume includes over 300 pages, and contains numerous tables, illustrations, and diagrams, which will be found of special value to the designer. We are pleased to add that it is admirably produced and bound, so that when opened at any place it will remain open in a manner convenient to the reader. The latter is a gratifying feature in a day when it is the fashion to provide books with binding that acts as an automatic self-closing spring, and is a continual source of worry to the busy man.

British Standard Tramway Rails and Fish-plates.—Issued by the Engineering Standards Committee. (London: William Clowes & Son, Ltd.) £1 1*s.* net; single sheets, 1*s.* each. July, 1903.

Further evidence of the valuable work being carried on by the Engineering Standards Committee, is given by the publication of the present series of findings relative to tramway rails. This pamphlet includes specifications for rails and fish-plates, in the first of which are defined the chemical composition of the steel to be used, the general dimensions of rail sections, normal lengths for straight and curved tracks, particulars of tests to be applied to finished rails, details relative to holes for various purposes, and facilities for inspection and marking. Somewhat similar recommendations are contained in the specification for fish-plates.

The sheets following the specifications are eleven in number, and each of the first ten sheets contains a full-size representation of a standard tramway rail, some being for straight and others for curved tracks, the weights per yard varying from 90 lbs. to 110 lbs. Dimensions are printed on each drawing down to the minutest detail, and there is no possibility of the slightest misunderstanding as to the meaning of the Committee. The last sheet of the series shows a standard tyre profile for tramcar wheels, giving the width of standard tyre for the five sets of rails illustrated on previous sheets, and correct wheel-gauges for the three track-gauges of 4 ft. 8½ ins., 4 ft., and 3 ft. 6 ins.

We observe that sets of templates of the various standard tramway rail and fish-plate sections can be obtained from the offices of the Committee. This is an excellent idea, which we hope will be appreciated by manufacturers.

BOOKS RECEIVED.

Properties of British Standard Sections. Issued by the Engineering Standards Committee. (London: Crosby Lockwood, & Son). Price 5*s.* net.

Notes on Track. By W. M. Kamp. (Published by the Author, 7418, Parnell Avenue, Chicago.) 2 vols. Price 15*s.* 5*d.*

Report of the Tariff Commission: Index to Iron and Steel Trades Section. (London: P. S. King & Son.)

Warships. By Ed. L. Attwood, M.Inst.N.A. (London: Longmans, Green, & Co.) Price 10*s.* 6*d.* net.

Modern Engines and Power Generators. By Rankin Kennedy. *Vol. III.* (London: The Caxton Publishing Co.) Price 9*s.* net.

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ENGINEERING PROGRESS.

Launch of the latest Cunarder, the *s.s. Caronia.*

THE latest addition to the fleet of the Cunard Steam Ship Company, viz., the *Caronia*, was successfully launched on July 13th last, by Mrs. Choate, wife of the Hon. J. H. Choate, United States Ambassador to Great Britain.

The *Caronia* is the largest ship which has been built on the Clyde, or in fact in any shipyard in England or Scotland, the dimensions being as follows :—

Length overall...	678 ft.
Breadth (moulded)	72 ft.
Depth to shelter deck	52 ft.
Draught of water (laden)	32 ft.
Displacement	29,800 tons
Gross tonnage	21,000 tons

The vessel is constructed to enable her to carry about 12,000 tons deadweight at a draught of 32 ft., and at a low consumption of fuel. In this connection it is notable that the committee of experts appointed by the Admiralty to test the economy of various types of boilers pronounced the "Saxonia"—built at Clydebank for the Cunard Company—as an exceedingly economical vessel, the machinery requiring only 13·4 lbs. of steam per hour, as compared with 16 lbs. in some naval ships for each horse-power, while the boilers produced 12·33 lbs. of steam per pound of coal ; in the naval ships the steam generated for the same amount of fuel was from 9½ to 11 lbs. In other words, each horse-power was attained for about 1¼ lb. (1·29 lb.) of fuel per hour—a very striking result.

The splendid resources of Clydebank are indicated by the fact that the keel-plate complete of this leviathan was laid in September, 1903, so that only 10½ months have been necessary to bring the ship to the launching stage.

The steel work is practically finished ; the very extensive carpentry and joinery work associated with the habitable quarters and the machinery is in an exceptionally far advanced stage. At the present time there has been worked into the ship's structure 13,500 tons. This was the launching weight of the ship. It is the heaviest weight that has ever been moved down ways into water. A measure of the enormous amount of work involved in the construction of the vessel to this stage is found in the fact that there have been used, thus far, in the structure, rivets weighing about 600 tons.

Many advantages have been made in connection with the structure of the ship, so as to enormously increase the strength, and to prevent the "working" which is too frequent in some modern vessels. The keel plate is of exceptional thickness (3 ins.). There is a very soundly built double bottom, which may be used for the carriage of water ballast, so as to bring the ship to a draught that will obviate rolling or pitching, and make her comfortable in any sea way. The total capacity for the water ballast is 3,450 tons. With the same object of rendering the ship steady in heavy seas very deep bilge keels have been fitted amidships for quite one-half of the length of the vessel. Besides the double bottom, which adds to strength, there are twelve bulkheads across the ship binding her together, and at the same time ensuring safety. Even were two of these compartments flooded the ship would still float. The stern frame is a massive and strong piece of work, weighing 65 tons. In order to give greater strength a considerable amount of the plating on deck and shell has been doubled in thickness, and the plates used have been of exceptional size, averaging about three tons in weight. Most of the riveting has been done by powerful hydraulic machines.

The *Caronia* has been built for the highest class of Lloyds' special survey, and also under direct survey to meet the requirements of the British Admiralty as a transport and armoured cruiser, and it is not stretching the point too far to say that she is the finest example of steel shipwork yet produced. From the first keel plate, this object has been before the builders and owners, and those who have watched the construction from stage to stage recognise that this object has been attained.

The *Caronia* is built on the well-known shelter-deck principle ; she has eight decks, most of which are given over for the carrying of passengers, and the wide experience, not

THE S.S. "CARONIA," CONSTRUCTED FOR THE CUNARD STEAMSHIP COMPANY BY MESSRS. JOHN BROWN AND CO., LTD., CLYDEBANK.

only of the builders but also of the owners, has resulted in an admirable system of cabin distribution and arrangement, so as to afford comfort on the voyage. The vessel has accommodation for the following number of passengers of the respective classes :—

1st Class	about	300
2nd Class	,,	350
3rd Class	,,	1,000
Steerage	,,	1,000
		2,650

If to this there be added the 450 officers and men constituting the crew, the total population of the ship will be 3,100. As the passenger accommodation has not been completed on board, it is not possible yet to give a description of it from personal observation.

The form of the ship is exceptionally fine, and looking at her, with all the shores and staging cleared away, as she stood ready for launching, a spectator would be struck with her splendid proportions and her "clean lines."

The vessel will, when completed, have two pole masts, rigged on the fore-and-aft system, with necessary derricks and cargo spans, and she has also the necessary steam winches to deal in the minimum of time with the 12,000 tons of cargo which she will carry. She will have two funnels.

In this vessel the principle of driving the auxiliary machinery by electric motors has been developed to a considerable extent, and special attention has been given to the disposition of fans for the ventilation of the extensive passenger compartments.

The navigating and deck machinery is necessarily of a powerful character. There are two steering engines of very heavy proportions, one under the water line, so that there is little chance of this important item for the navigation of the ship being affected by gun-shot when the vessel is used as an armed cruiser ; the other steering engine is placed on a higher level. The rudder stock is extended up to the highest gear, but can be operated by either of the two steering engines. The capstan and windlass gear for working the heavy anchors are probably the heaviest that have been fitted to any merchant ship. The navigating bridge is placed in a very high position, so as to command a wide circle, and the captain has, within arm's-reach, apparatus whereby he can control every movement, both at sea and while entering docks.

The vessel has been designed to maintain a continuous speed at sea of 18 knots, and to this end propelling machinery of the quadruple expansion type, for driving twin propellors, has been fitted. Each of the two sets of engines is entirely self-contained, with all the auxiliary machinery, and each has four cylinders, all adapted for a stroke of 66 ins. All the working parts have been so arranged as to ensure that there will be the minimum of vibration.

Owing to the considerable power to be developed, and to the consequent large size of the cylinders, some of them are fitted with two valves, and assistant cylinders are provided for facilitating the working of these valves.

This is only one of the many instances where experience and care have been utilised to ensure perfect operation. The shafting, which is of steel, has been manufactured at the Sheffield works of the builders' firm. The main condensers are cylindrical, and the circulating water is supplied by two powerful centrifugal pumps, each of the pumps having two engines in connection therewith. Every detail in the steam plant is of a type to ensure a high economy as well as reliability in working.

The boiler installation includes eight double-ended and five single-ended boilers, working in all cases at a pressure of 200 lbs. per sq. in. These are arranged in two separate boiler rooms, and the exhaust gases pass through two elliptical funnels, which rise to a height of 135 ft. above the level of the furnace. The boilers are fitted with Howden's heated forced draught, supplied by two large fans, each driven by two engines.

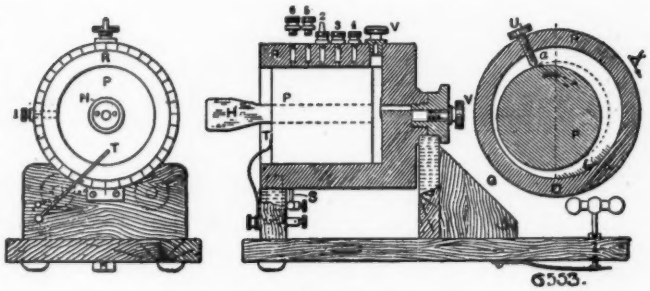
The builders, Messrs. John Brown & Co., Ltd., of Clydebank, have in course of construction a sister ship to the *Caronia*, which will be fitted with turbine machinery, as well as a vessel of 760 ft. in length, which is being constructed under agreement with the Government to attain a sea speed of not less than 24½ knots. This vessel will also be driven by turbine machinery, and will represent the highest attainment in naval architecture and marine engineering.

Air as a Lubricant.

ALTHOUGH oil is generally employed as a lubricant, it has long been known that other substances, such as glycerine, nitrobenzine, and even water, are capable of being employed in this capacity.

A writer in a recent number of *Machinery* describes an interesting experiment tending to prove that air is capable, under certain conditions, of becoming a lubricant.

The experiment was made at the Worcester Polytechnic with the apparatus illus-



AIR AS A LUBRICANT.

trated in the accompanying figure, and which consists of a cast-iron cylindrical bearing R, in the interior of which is fitted a steel roller or plug P, corresponding to a shaft. The diameter of the roller is 152 mm., its length 158 mm., and its weight 23 kg. The interior of the bearing and the exterior of the roller were accurately finished, the difference in diameter being only about 4/100 mm. The bearing is closed at one end, and is provided with two plugs, V and V', the removal of which permits the air to escape on the roller being inserted. When the latter is in place, that is to say, about 19 mm. from the end, the plugs are inserted, the air remaining in the bearing serving to limit the movement of the roller in a horizontal direction. The roller is revolved by hand by means of a handle H, suitable gearing being employed when high velocities are required.

The cylinder R is mounted on a wooden support, on which it can be rotated in order to bring any of the apertures numbered 1 to 6 into the desired position. A mercury manometer can be inserted in any of the apertures, and an electric bell is introduced into a circuit comprising the bearing R, and the roller P, contact with the latter being made at T.

When at rest, the roller is supported by the cylinder, metallic contact being verified by means of the electric bell; and this is the case even when the roller is slowly revolved.

When, however, the velocity is increased, the bell ceases to ring, which shows that the contact has been broken by a stratum of air having entered between the fixed and moving bodies.

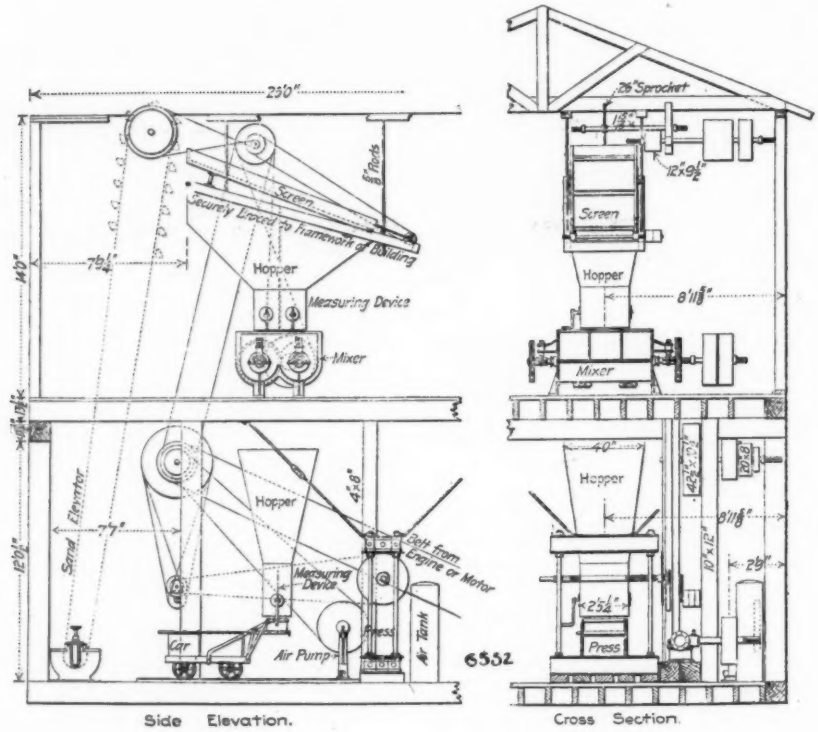
A small difference in diameter between the bearing and roller is indispensable for the formation of this layer of air, and it is possible to demonstrate that the thickness of this layer is not the same at all points, in other words, that the roller is not at the centre of the bearing. A screw is introduced in the opening (1), and during the rotation of the roller the screw is turned until contact is made at a point a, which is announced by the ringing of the electric bell. If, then, the roller is turned in the direction of the arrow contact ceases, but is re-established when the point b is reached. On the other hand, when the roller is turned in the opposite direction, contact continues. The two surfaces are nearest to each other at the point G, which is shown by inserting there a contact-screw and turning the roller first in one direction and then in another, the current ceasing in both instances. The position of this point varies with the speed of revolution, the axis of the roller tending to coincide with that of the bearing as the speed increases. Readings taken by the manometer show that the pressure existing in the layer of air is unequal, being above that of the atmosphere in the lower portion of the bearing, and *vice versâ*.

From this it is deduced that in the case of ordinary bearings an analogous difference in pressure exists in the lubricant, which latter should therefore be introduced at a point where the pressure is not above that of the atmosphere.

A Plant for Manufacturing Concrete Blocks.

THE rapid increase in the demand for concrete blocks for building and constructional purposes has led, in the United States, to the development of a special industry engaged in their manufacture. A new plant for the manufacturing of hollow concrete blocks is thus described in a recent number of *The Engineering News*.

The plant has the Mississippi River on one side, from which is taken the sand used in the concrete, and on the other side is a railway siding. The building is 24 ft. by 48 ft., and includes a two-storey section 24 ft. square and 34 ft. high, in which is contained all the machinery. The one-storey portion is used for the storage of the green blocks, and is supplemented by a shed 72 ft. long. After the blocks are sufficiently dry to handle, which is about 48 hours from the time they



PLANT FOR MANUFACTURING CONCRETE BLOCKS.

leave the press, they are piled in the yard. The arrangement of the plant is clearly shown in the accompanying figure.

The sand pumped from the river is delivered into the boot of a bucket-elevator, about 6 ft. below the first floor. This elevator discharges at the top of the building into a screen which separates the sand and gravel, and delivers them into two storage bins over the concrete mixer, on the second floor. The cement is stored in a similar bin, and the bins feed into the chute fitted with a measuring device. This consists of a cast-iron cylinder with a slot 5 ins. wide extending its entire length, the ends of the cylinder being closed. It is operated by a crank handle on a rod which passes through the centre of the cylinder. A Broughton concrete mixer is used, and the proportions are usually 1 to 5.

After a thorough mixing the concrete is dumped from the mixer into another hopper located behind the press, and from here it is again measured out, by a device similar to that above-mentioned, into a truck carrying a box of sufficient capacity for material for one block. The truck runs on a narrow-gauge track, and upon being filled is run forward a distance of about 5 ft., bringing the box which it carries directly over the mould of the press. The box has a false or movable bottom, operated by a lever, by means of which the material is delivered to the mould.

The press is now run down, compressing the block to the proper thickness, and at this point the mould is opened. Two arms attached to the follower of the press are thrown down to hang in a perpendicular position, and engage with a plate on which the block is made. After this operation the press is started on its upward travel, carrying the block with it to clear the top of the cores. The block is then placed on a rack, leaving

the press in readiness for another block, and the racks are carried away on trucks to the storage room.

The power to run the plant is furnished by a 7½-h.p. 220-volt 60-cycle Westinghouse induction motor, running at a speed of 1,120 revolutions, and driving the line-shaft at 300 revolutions per minute. From the line-shaft belts are run to an automatic stop and reversing gear, similar to those used in elevator work, the gear being connected through another set of belts and a short countershaft to the press, which is of the toggle pattern, and gives a pressure of 120 tons. The press is automatically stopped at the extreme limits of its travel (about 13 ins.), compressing the block to an even thickness of 7¾ ins. and of a uniform density. It is claimed that with this machine three men and two boys can easily turn out and care for 300 blocks per day of ten hours. At this rate the cost of labour would be from 1¼*d.* to 1½*d.* per block.

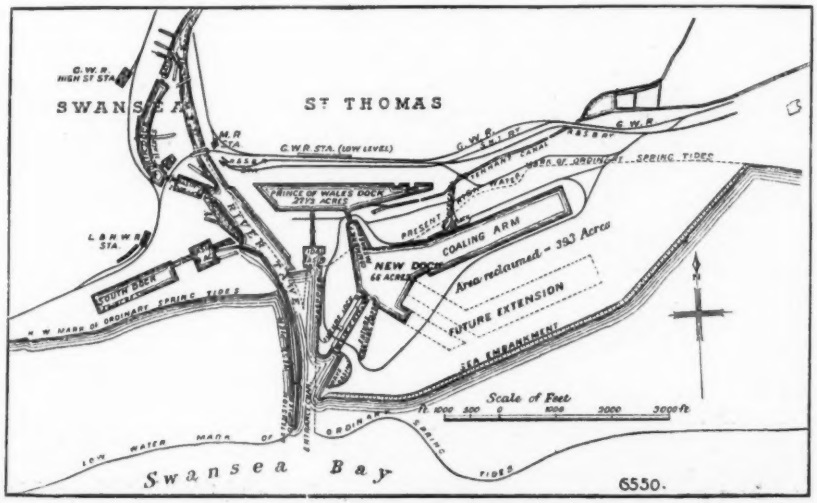
A New Dock for Swansea.

ONE of the principal events of the past month was the visit of the King to lay the foundation stone of a new dock at Swansea, which should prove the means of causing a rapid development of traffic at that port.

The existing accommodation was found by the trustees to be inadequate to deal with the increasing tonnage, which in the last decade has increased by no less than 1,500,000 tons; and, further, steamers of very large size have been unable to enter, hence, in 1901, application was made to Parliament for powers to construct docks 63 acres in extent.

The new dock will be constructed on the foreshore to the east of the existing entrance channel, and the whole of the works, with the exception of the passage connecting the dock with the Prince of Wales Dock, will be below high-water mark of ordinary spring tides, on a site which is of little value for anything outside dock purposes, and has, in consequence, been acquired at a comparatively low figure. The area of the existing docks amounts to 60 acres, so that the new undertaking will more than double the present accommodation of this port

Vessels will enter the dock from a lock situated near the end of the existing east pier, 875 ft. long between the inner and outer gate cills, and 90 ft. wide at coping-level. There will be a depth of water on the outer cills of 40 ft. at the high-water mark of ordinary spring tides, and 12 ft. at low-water mark ordinary spring tides, and 32 ft. 3 ins. and 19 ft. 9 ins. at neap tides respectively. It will thus be noted that ships of the largest size will be able to enter at any tide in the year, and that the ordinary-sized tramp-steamer which the port now accommodates



PLAN OF SWANSEA DOCKS, SHOWING FUTURE EXTENSION.

will be able to enter and leave at practically any state of the tide throughout the year.

The depth of 12 ft. over the outer cill at low water is greater than that of any other port in the British Channel under similar conditions of tide, with the exception of Barry, where the depth at low-water ordinary spring tide is 13 ft. 9 ins. In order to exclude the tidal waters from the site of the works a rubble embankment, about 1¾ ml. long, will be tipped, faced with heavy blocks of stone, forming a water-tight enclosure of about 400 acres, within which the dock works proper will be constructed. The area thus reclaimed provides for a dock with a water area of 107 acres, of which it is only proposed now to construct 66 acres, leaving the remainder for future extension when the necessity arises.

To protect the entrance, the present west pier will be extended 800 ft., and a new east pier be built with an approach jetty extending from it to the lock, alongside of which ships will "bring up" before entering the lock. The approach jetty will be of timber work, sufficiently open to allow of wave action expending itself before reaching the outer gates of the lock, in a basin constructed for the purpose.

The lock will have vertical side walls and a flat invert throughout its entire length, so that the depth of water over the cills will be maintained practically for the full width of the lock. The angle at which the lock is placed relative to the quay walls of the dock will be such that the largest vessel the dock can take in, after it has passed through the lock, will be able to swing without interfering with any ship berthed alongside the adjacent quays. The dock walls will be vertical, with ample quay space behind them for warehouses and railway sidings. The central position of the dock will be used for general trade. The eastern end will be reserved for a coaling arm. The Great Western Railway Company have taken 1,000 ft. of frontage on the north side of the coaling arm, and will put up coaling appliances of the most modern type, involving the use of movable coal hoists, all worked on the high level, so as to have the whole of the quay space below free for the main line traffic round the dock. The other railway companies are also negotiating for frontages on the southern side of the coaling arm.]

The length of quays for general trade will be 7,350 ft., for coaling purposes 3,200 ft., or an inclusive total of 10,550 ft.

The joint engineers for the dock are Mr. P. W. Meik, M.Inst.C.E., and Mr. A. O. Schenk, M.Inst.C.E., the Harbour Trustees' engineer. The resident engineer is Mr. R. S. Oldham, A.M.Inst.C.E., and the contractors Messrs. Topham, Jones & Railton, Westminster.

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Railway Notes.

Electric Gins for Lifting Locomotives.

THE task of raising a heavy modern locomotive or bogie coach clear of its wheels by means of hand gear of the ordinary type, is one involving an altogether disproportionate amount of labour and time. A new method has, however, been recently introduced for executing this class of work by the application of electricity, which, by the simplicity of action and economy in working, promises to have a vogue.

As may be seen from the illustration, the new method consists in the employment of four gins, arranged two on each side of the locomotive to be lifted. To allow of easy transport, each gin is provided with three wheels, which can be raised clear of the ground when the gin is in use. The gins are operated by means of an electric motor which is mounted upon wheels, and can therefore be easily transferred from one place to another. The motor transmits power to the pair of gins nearest to it by means of telescopic shafts, which work between so-called "hook" joints, which also serve as couplings. Each telescopic shaft consists of an axle fixed in a steel tube in such a manner that it is prevented from rotating, but can easily slide therein, so that the gins can be easily adjusted to locomotives of various sizes. The "hook" joint couplings enable the telescopic shafts to work also in an oblique position, which does away with the tedious process of levelling up the gins. These couplings are so constructed that they can be easily coupled and uncoupled without the use of any tools, so that the gins can be rapidly adjusted for power or if necessary hand-driving.

The transmission of energy to the opposite set of gins is again effected by means of telescopic shafts which actuate a conical gear wheel with which each gin is fitted. As one of these two shafts must of necessity always obstruct the track over which the wheels of the locomotive are to be run in or out, the facility with which the "hook" joint couplings may be connected or disconnected is of great importance, as the locomotives to be lifted can thus be changed with very little loss of time.

By means of this plant, the weight of which is about six tons, a locomotive can be

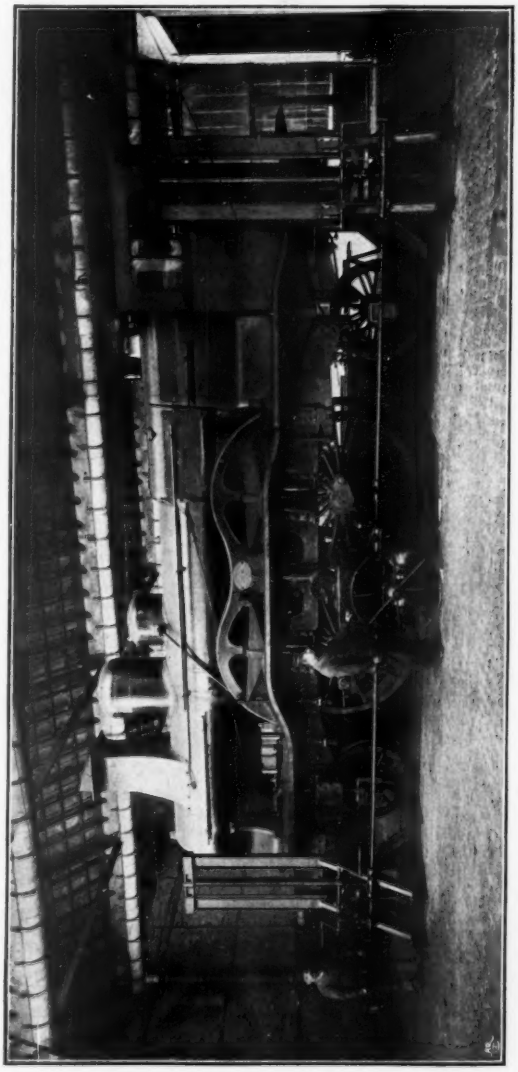
lifted to he height of 5 ft. in 12 minutes. As to first cost and subsequent maintenance, the makers furnish figures which compare extremely favourably with the existing methods of power or hand-lifting.

Experiments Relating to Locomotive Chimneys and Blast Nozzles.

REFERENCE was made in our last issue to the valuable research work that had been conducted with the experimental locomotive testing plant at the Purdue University, U.S.A. Some of the more recent experiments conducted by Professor Goss at that institution have had for their object the establishment of the relation which exists between the exhaust, the position of the blast pipe, and the dimensions of the funnel; and are of particular interest by reason of their importance and the conclutions which have been drawn from them. They were carried out on a 2-4-type locomotive installed in the laboratory, which was furnished with seven separated exhaust nozzles, the upper levels of which varied from 0·254 m. to 0·508 m. above the axis of the boiler. The common diameter of the nozzles was 0·107 m. Eight different chimneys were provided, four of which were cylindrical in shape and four conical with an inclination of the generating line of $\frac{85}{1000}$ to the vertical. The minimum diameters of the chimneys of both kinds were 0·247 m.; 0·298 m.; 0·349 m; 0·400 m.

Their height could be varied by means of suitable collars in such a way as to make four different funnels, as shown at *A B C D*, Fig. 1.

Naphtha was used for firing, to eliminate any irregularities in the generation of steam which would have followed upon the use of an ordinary fire. The depression in the smoke box, pressure in the blast pipe, the degree of cut-off, the speed and power developed were carefully noted duriug each experiment. Over 1000 observations were made at speeds ranging from 32 to 96 kilom. per hour, and with steam admissions of from 19 to 35 per cent. The blast pipes are numbered from 1 to 7, Fig. 1; the cylindrical chimneys are distinguished by the odd



ELECTRIC GIN HOIST FOR LOCOMOTIVES AND ROLLING STOCK.

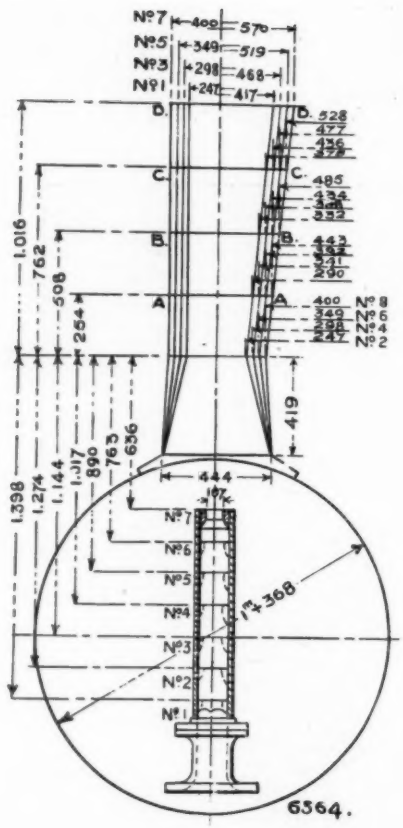


FIG. 1.

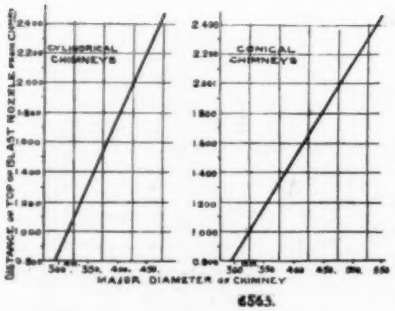


FIG. 2.

numbers, 1A, 3C, etc.; those of conical shape being referred to as 2B, 4C, etc.

The results of the trials are given in the accompanying tables :—

1. CYLINDRICAL CHIMNEYS.

Type.	Depression in Millimetres of Water for the Height of the Blast Nozzle.						
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
1A	31	36	36	36	29	28	26
3A	38	45	51	55	56	51	46
5A	34	44	54	59	66	68	64
7A	25	36	55	59	63	76	72
1B	41	41	41	38	30	30	28
3B	54	55	61	61	56	53	46
5B	51	61	66	71	74	84	63
7B	44	54	69	73	73	91	76
1C	45	41	38	36	33	32	26
3C	64	66	66	66	61	56	49
5C	64	74	76	81	76	76	64
7C	59	72	83	81	91	93	76
1D	45	45	41	38	31	28	26
3D	69	69	71	68	58	54	51
5D	79	82	91	84	76	81	68
7D	73	81	93	89	101	104	78

2. CONICAL CHIMNEYS.

2A	35	41	45	53	51	51	46
4A	34	45	56	64	66	73	65
6A	28	41	51	58	70	73	73
8A	20	28	38	51	66	77	73
2B	49	55	66	71	63	56	54
4B	49	58	71	76	78	84	78
6B	41	51	71	73	88	89	81
8B	30	44	55	60	76	86	81
2C	61	68	76	77	79	61	51
4C	59	71	81	84	92	98	85
6C	53	63	77	83	99	99	91
8C	40	54	71	71	91	91	91
2D	71	77	81	89	91	69	59
4D	71	87	91	93	96	108	98
6D	63	70	83	97	102	102	107
8D	48	60	83	77	101	101	101

Inspection of this table shows that, in the case of this experimental locomotive, the best results were obtained with the height of blast nozzle No. 6, which corresponds in the case of this engine with a distance of 0·380 m. approximately from the axis of the boiler. As regards the type of chimney it will be observed that it is the highest, viz., *D*, about 1·430 m. total height, which conduces to the greatest depression in the smoke box. The cylindrical chimney No. 7 of 0·400 m. diameter and the conical chimney No. 6, 0·349 m. minimum diameter, gave the best results; while, other things being equal, the conical type has the advantage of the cylindrical.

The table also furnishes the means of determining the best position for the blast nozzle in an existing locomotive. Suppose, for example, that the machine under consideration has a cylindrical chimney 1·200 m. high, and a diameter of 0·350 m. correspond-

ing to type 5C, it will be seen that the maximum depression is obtained for position of blast nozzle No. 4, viz., about 0·125 m. above the boiler axis.

From these experiments Professor Goss has deduced the following formulæ by which may be determined the proper diameter of the chimney of the smoke box, and the position of the blast nozzle. For cylindrical chimneys :—

$$d = (0{\cdot}246 + 0{\cdot}0000048\ H)\ D - 0{,}19\ h.$$

For conical chimneys :—

$$d = C\ 0{\cdot}25\ D - 0{\cdot}16\ h,$$

where d is the minimum diameter of the chimney D = the diameter of smoke box, H, the height of chimney above the smoke box, and h the distance of the blast orifice from the boiler axis ; h being positive or negative according as the blast nozzle is above or below this axis.

The accompanying curves have been plotted from the mean results obtained from these experiments, and by their means the position of the blast nozzle may be determined when the major diameter of the funnel is known.

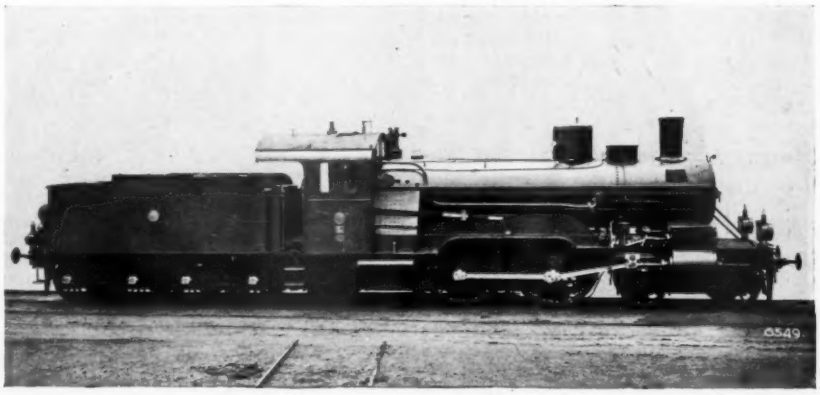
These experiments may be regarded as the complement of those conducted by M. Von Borries, in 1896, on the same subject ; the outcome of which was that it was preferable to use a chimney of conical shape, that the diameter should be small enough to cause the cone of exhaust steam to strike the barrel of the chimney and of such a length that the steam would form a fluid piston, capable of setting up by its movement a sufficient depression in the smoke box.

As a general conclusion, Professor Goss advocates this exclusive employment of conical chimneys, having an inclination of the generating line of $\frac{50}{1000}$ in place of $\frac{83}{1000}$, to replace the curve given in Fig. 3, which only applies to a blast pipe with a diameter of about 0·107 m. by the more general formula, $d^1 e^1 = 0{\cdot}14\ l + 1{\cdot}8\ \delta$, which takes into consideration the diameter of the blast nozzle which can evidently vary according to the type of locomotive. As for the diameter, δ, this may be deduced from the following formula : $\delta = 0{\cdot}115,\ \sqrt{\frac{S\ G}{S + 0{\cdot}1\ G}}$, where S and G represent the heating surface and grate area respectively. Finally, the height, H, of the chimney above the smoke box, can be limited to $0{\cdot}5\ l$, if the necessary space is lacking.

Practice has shown, particularly in the case of certain British locomotives of recent construction, that a reduction in the length of chimney does not interfere sensibly with the blast. Certain complementary experiments have also been made at Purdue, to determine the advisability of prolonging the chimney on the interior side of the smoke-box. Professor Goss has shown that this practice, in vogue on several American and European locomotives, has caused a diminution in the effect of the blast, and it is therefore preferable to abandon it.

A Four-Cylinder Atlantic-Type Express Locomotive.

ONE of the high-speed locomotives that were used in connection with the official high-speed experiments on the Marienfelde-Zossen line has been shipped to America and is being exhibited at the World's Fair.



4-4-2-TYPE LOCOMOTIVE USED IN THE MARIENFELDE-ZOSSEN HIGH-SPEED EXPERIMENTS.

This locomotive, built by the Hanoverische Maschinenbau Gesellschaft, vormals Georg Egestorff, Linden von Hanover, is a four-cylinder compound express engine of the Atlantic type, and is fitted with a von Borries simplified valve-gear and a Pielock superheater, giving a heating surface of 310 sq. ft. and superheating the steam to about 300 degs. Cent. The boiler has 241 solid-drawn iron tubes of nearly 2 ins. outside diameter and 14 ft. 7 ins. length between the tube plates.

The principal dimensions are the following :—

Diameter of cylinders	14 ins. to 24 ins.
Stroke of piston	24 ins.
Diameter of driving wheels...	6 ft. 6 ins.
Diameter of bogie wheels	3 ft. 3⅜ ins.
Wheel-base of coupled wheels	6 ft. 10½ ins,
Wheel-base of bogie	6 ft. 6½ ins.
Total wheel-base	29 ft. 3⅜ ins.
Working pressure	199 lbs. per sq. in.
Grate area	29 sq. ft.
Heating surface, fire-box	108 sq. ft.
Heating surface, tubes	1,504 sq. ft.
Heating surface, superheater	310 sq. ft.
Heating surface, total	1,922 sq. ft.
Number of tubes	241
Outside diameter of tubes	2 ins.
Length between tube plates	14 ft. 7 ins.
Weight, empty...	119,500 lbs.
Weight in working order	132,700 lbs.
Adhesive weight	67,000 lbs.
Water capacity of tender	4,182 imp. gall.
Coal space of tender	6 tons.
Weight, empty	41,850 lbs.
Weight in working order of tender ...	97,000 lbs.

Before being shipped to St. Louis the locomotive was proved able to haul vestibuled car trains of 300 tons weight with a constant speed of 62 miles per hour on the level and 50 miles per hour on grades up to 1·200.

The starting is effected smoothly and without any difficulty by a direct admission of live steam into the steam chests of the low-pressure cylinders. This admission is governed automatically by the regulator-valve.

So far the Prussian State Railways have twenty-nine of this type of locomotive running or under construction, a lot of nineteen having been ordered this year.

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Direct Casting from the Blast Furnace.

THE most southerly district in which iron founding is carried on is Northamptonshire, and being separated from the metropolis by a distance of only some 60 miles, the iron-masters of this locality have long looked upon the Metropolis as a most desirable market.

As, however, until recently the output has consisted mainly of pig-iron, their aspirations as regards London were not capable of realisation, and, in fact, South Staffordshire was practically the only outlet for their material, in which district it was mainly used in the manufacture of wrought-iron, although some portion of the pig output was distributed to the foundries and forges of the Midlands, where it was re-melted and worked into manufactured articles. The steadily increasing use of soft basic steel, which can be produced at a lower cost per ton than Staffordshire wrought-iron, has, however, diminished the use and consumption of Northamptonshire pig-iron.

Coupling this circumstance with their recognition of the fact that the modern tendency in manufacture is to eliminate all intermediate processes and to bring the source of production as close as possible to the district in which the finished article finds a use or a market, Messrs. Thomas Butlin & Co., Ltd., of Wellingborough, who, established in 1852, were the first to smelt Northamptonshire iron, determined upon an exhaustive series of experiments with the view of making castings direct from the blast-furnace and local ores, and so take advantage of the close proximity of the works to London. These were carried out by Mr. W. H. Butlin, the chairman and managing director of the firm, with the assistance of the foundry manager, Mr. W. Wright. As a result the firm first made valves, valve-seatings, bogie-wheels, etc., for their own use, and their suitability having been demonstrated, they have now entered upon the process upon a manufacturing scale. A suggestion of the success attained is afforded by the fact that they are now carrying out contracts, at the rate of about

MR. W. H. BUTLIN, B.A., CHAIRMAN AND MANAGING DIRECTOR OF MESSRS. THOS. BUTLIN AND CO., LTD., WELLINGBOROUGH.

FIG. 1.—CASTING TUNNEL SEGMENTS DIRECT FROM BLAST FURNACE: SEGMENT FOUNDRY.

100 tons per week, for tunnel segments for the Great Northern and Strand Tunnel Railway, and of special castings for the King's Cross and Piccadilly line.

A week or two ago, this important development in the Northamptonshire iron district was celebrated under the presidency of Lord Lilford, by the opening, at the Irthlingborough Iron Works, Wellingborough, of a new foundry under the auspices of Messrs. Thomas Butlin & Co., Ltd., and the closely allied Northamptonshire Direct Castings Co., Ltd.

Casting direct from the blast furnace is, of course, not a new development in metallurgy; but owing to the demand for complicated castings in which exact demands involving remelting in the cupola, have to be met, the practice has not been much followed, except for rough castings for works purposes or for very cheap shapes of cast-iron goods. As the efforts made in the latter direction have not in all cases been successful, the means adopted at Messrs. Butlin's works are of considerable interest. The success has been attained, not so much by mechanical means as by a careful study of the chemistry of the subject by Mr. W. H. Butlin himself. Suitable combinations not only ensure economy of fuel, but give greater uniformity in the resultant metal. The Northamptonshire ore may be described chemically as a brown hematite from the inferior oolite formation; it is a hydrated sesqui-oxide of iron containing about 6 to 7 per cent. of water of combination, in addition to the ordinary moisture found in it. The yield of the raw ores averages in bulk from 34 to 37 per cent., but a certain proportion of calcined ore is used to augment the yield.

As good iron is accompanied with good slag, the quality of the slag was regarded during the experiments as an index to the character of the iron. What was aimed at as typical was to get a slag which contained about 15 per cent. of alumina, 32 to 33 per cent. of silica, and 40 to 43 per cent. of lime. The result was a combination fusible at a comparatively low temperature. The blast used is preferably at about 900 degs. Fahr., so as to get stronger reducing gases in the blast furnace. Special care is taken in the selection of the limestone to ensure as far as possible that it will be porous, and that it will thus flux more readily, and facilitate the admittance of graphitic carbon into the iron.

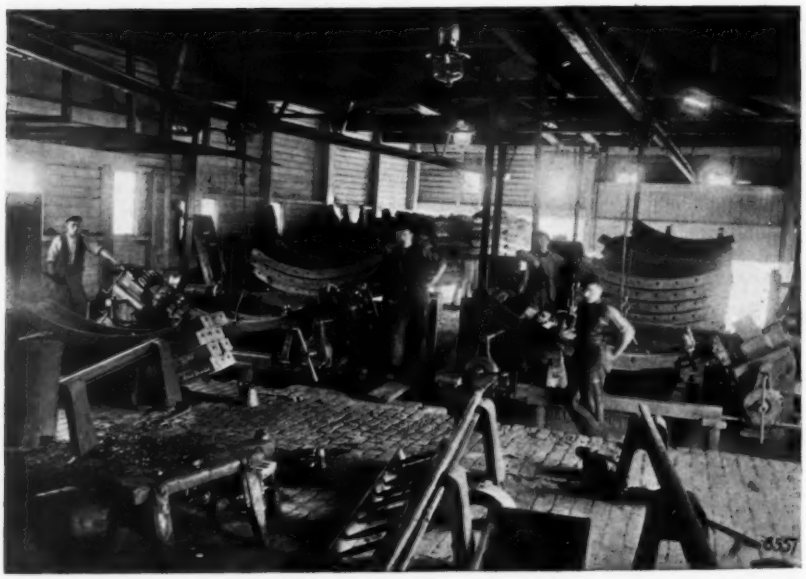

FIG. 2.—CASTING TUNNEL SEGMENTS DIRECT FROM THE BLAST FURNACE: MILLING SHOP.

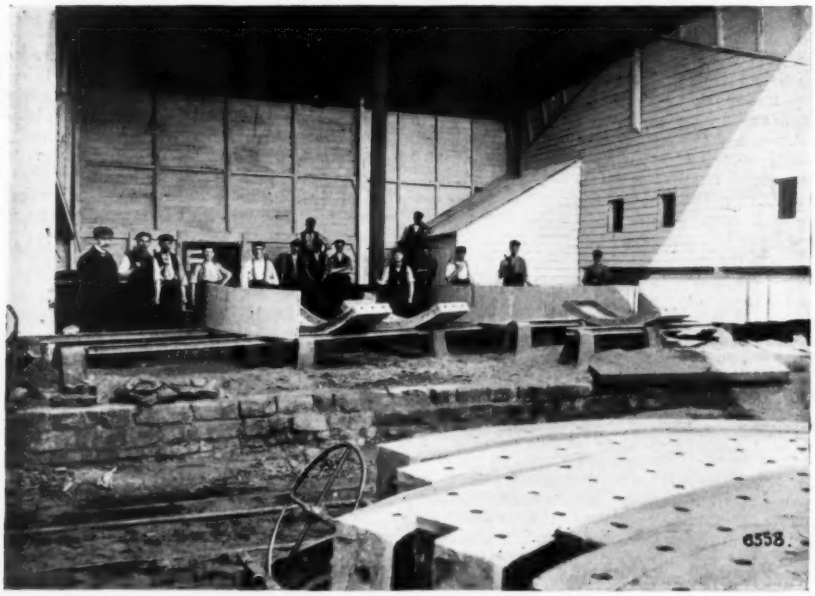

FIG. 3.—CASTING TUNNEL SEGMENTS DIRECT FROM THE BLAST FURNACE: FETTLING SHED.

Another important element in success has reference to the quality and purity of the coke used, so as to ensure that it will contain 90 per cent. by weight of carbon, and not more than 7 per cent. of ash. The practice is to weigh it in boxes of a cubic yard capacity after it has been broken into cubes about the size of a walnut ; and if the weight of this exceeds a given standard, suggesting a larger proportion of ash than is desirable, the coke is analysed. The usual floating test is also applied. The care taken in connection with limestone and coke obviates a higher temperature in the blast-furnace than would otherwise be necessary, and gives a sound and solid casting.

The fuel consumption—about two-thirds coke and one-third hard Yorkshire coal—is at the rate of 22½ cwts. per ton and the make—principally foundry iron—has the following constituents:

Graphitic carbon ...	2·85
Silicon	1·92
Sulphur	0·10
Manganese	0·24
Phosphorus	1·19

Owing to the circumstance that the district is deficient in hard rocks suitable for road making, the iron works are in the position of being able to dispense with a slag tip. The cinder as it runs from the furnace is moulded into rectangular blocks of about 13 cwts. in side-tipping cast-iron bogies, which chill rapidly. The blocks, when subsequently cooled, are roughly broken by hand and passed through a Blake rock breaker, with drum sizing sieves, which reduces the bulk up to road metal or railway ballast size, the finer chippings finding a use as ballast in making granolithic slabs, and a considerable quantity has also been used in decorative moulded work of the North British Hotel at the Waverley Station in Edinburgh.

There are two blast furnaces working on this system at the Irthlingborough Iron Works, their combined capacity being about 700 tons per week.

The equipment of the foundry though simple, is nevertheless very efficient. The casting channels have been extended beyond the pig beds of the furnaces to the side of a sunk pit containing the receiving ladles, which vary in capacity from 3½ to 5 tons, and are taken away by a locomotive crane running on rails to the segment foundry, a view of which is shown at Fig. 1. This is a rectangular building of 100 ft. by 45 ft. open at the ends, with a railway running down the middle separating the floor space for the moulds. The ladles are manipulated by means of differential pulley-block buckles mounted on bogies, running on overhead joists. The tunnel segments and other special castings are made in the foundry with ordinary sand. The specified test for the metal is a load of 28 cwts. on a bar 3 ft. 6 ins. long by 2 ins. by 1 in. set 3 ft. between

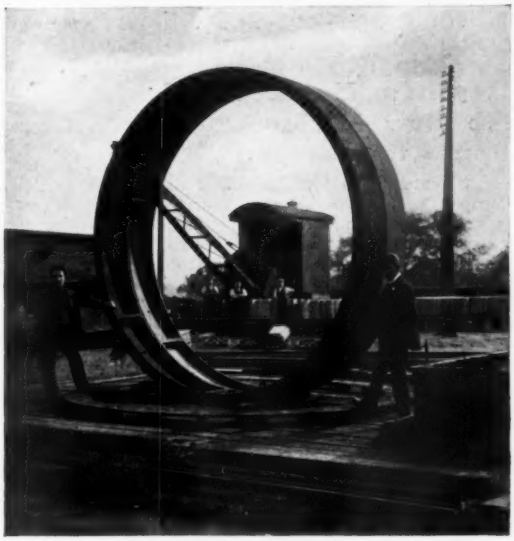

FIG. 4.—A COMPLETE TUNNEL RING.

centres. The segments weigh about 5 cwts., being 6 ft. 7 ins. long, 20 ins. wide, with plate ⅝ in. thick, and flange 1⅛ in. thick, and are formed with 4¾-in. flanges on all four sides, so that they can be bolted together to make a complete ring 11 ft. in diameter: such a ring is shown in Fig. 4. The flanges, in accordance with the general practice, are on the inside, forming ribs to resist exterior compression. The ends of each segment are milled so as to ensure a good bedding and to make the circle absolutely true. This milling work (*see* Fig. 2) is done on special tools made by Messrs. Kendall having beds

curved to the shape of the finished ring upon which the segment is secured by bars passed through the end bolt holes, and both flanges are milled simultaneously. Whitworth steel is used for the cutters, and the segments, which are 20 ins. wide, are milled in about seven minutes, excluding the time taken for fixing. The finished segments are removed from the planing machines by the crane and deposited on a pair of rail bearers beneath which is a coal fire which heats them up to the temperature required for receiving the protecting bituminous coating. Thus in the completion of the segments, as well as the intermediate stages, economy of manufacture is ensured, and we understand that the contract price is considerably less than that formerly found necessary.

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Heysham Harbour and the New Midland Route to Ireland.

ON September 1st the Midland Railway Company's new cross-channel service between Heysham and Belfast was inaugurated. The possession of a port of their own, with the necessary fleet of steamships for dealing with their Irish and Manx traffic, has long been a desideratum of the company, and only after the expenditure of a large sum of money and eight years' work has it been realised. In view of the importance of the new route to both the public and the company it may be of interest to briefly pass in review the principal features of the harbour at Heysham and of one of the new boats.

The new harbour, a Bill for which was promoted by the Midland Company in 1896, is practically completed as far as cross-channel traffic is concerned, and is situated on the Lancashire coast, 3 mls. south of Morecambe.

To the latter place the Midland Company have for a long time run a service of trains in connection with Messrs. Lairds' steamers sailing to Dublin and Londonderry; but Morecambe Harbour proved very unsatisfactory, owing to the fact that the boats can only get in or out at high-water.

The other route by which the Midland Company have been able to deal with their north of Ireland traffic has been in joint arrangement with the Furness Railway Company *viâ* Barrow-in-Furness, to which place a railway connection has been in existence for a considerable time, the passage to Belfast or the Isle of Man being made by one of the steamers belonging to Messrs. James Little & Co. of Barrow-in-Furness. Here, again, insufficient depth of water rendered Barrow unsatisfactory as a port.

These objections will, of course, not apply at Heysham, as the site was chosen primarily because of the good sea approach, which affords a minimium depth at low-water

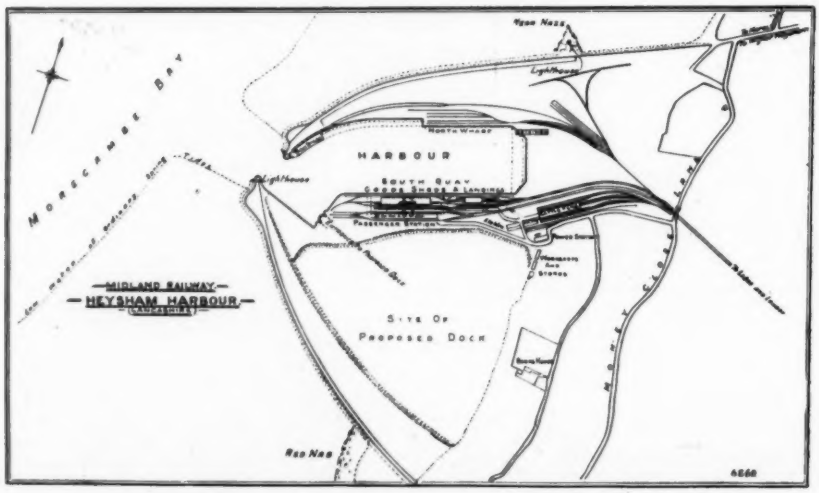


FIG. 1.—PLAN OF THE NEW HARBOUR AND PROPOSED DOCK AT HEYSHAM

FIG. 2.—HEYSHAM HARBOUR: VIEW OF THE ENTRANCE AND ROUNDHEADS.

ordinary spring tides of 40 ft. up to the entrance of the harbour. Inside the harbour the depth is 17 ft.

It will be seen from the accompanying plan that the basin is enclosed within two breakwaters, projecting from points situated considerably over a mile apart, and gradually converging until, at the mouth of the harbour, they are separated by a distance of only 300 ft.

The area enclosed by the arms of the breakwater consisted of undulating land, aggregating 150 acres, which was, for the most part, reclaimed from the sea. The excavations, which were commenced during the construction of the breakwaters, involved the handling of some 3,500,000 cub. yds. of material, and its removal was carried out in a very expeditious manner by the use of grab-excavators, steam navvies, and a German excavator running on rails and operating on the bucket-ladder principle, the material being tipped into wagons from the buckets. This excavator alone dealt with no less than 2,400 cub. yds. of sand per day. The breakwaters extend for a length of 4,000 yds., and are 600 ft. wide at the base and 170 ft. wide at the ends; at the top and in the narrowest part the width is 35 ft. The outer walls exposed to the sea rise to a height of 14 ft. above high-water ordinary spring tides, and are of rock rubble construction, the rubble being faced with dry stone pitching, where the slope is $1\frac{3}{4}$ to 1. Inside, the walls are constructed of 7–1 concrete, with a 9-in. facing, in which the proportion is improved to 5–1. In the case of one small portion on the northern arm, however, the construction is rough pitching. The maximum thickness of the walls at the bottom is 29 ft., stepped at the back to 6 ft. 6 ins. at coping level; the height is 9 ft. above high-water ordinary spring tides, which increases to a maximum, at the ends of 15 ft. The backing is for the most part ordinary sand. The two arms of the breakwater terminate in roundheads, forming the harbour entrance. They are of massed concrete with an ashlar coping, and are carried on monoliths 55 ft. in diameter, sunk to a depth of $42\frac{1}{2}$ ft. below the harbour bottom. The constructional features of these monoliths are of the greatest interest, and those desiring details may find them in a very complete article in *Engineering*, Aug. 12, pp. 201–2. Wing-walls have been constructed outside in both cases, the roundhead on the north side having one also on its inner side.

On the southern roundhead a lighthouse has been erected, in a straight line with which, on the land side to the north-east and shown on the plan, is a leading light, the purpose of the combination being to give the line of direction to the approaching ships of the deep water leading up to the harbour entrance.

The basin enclosed is 2,400 ft. in length and 700 ft. wide, and has, as before stated, a depth at low water of 17 ft. The landing facilities, available at all states of the tide, are of the most complete description, and the total quay length amounts to 3,000 ft.

At the seaward end of the harbour, on the north side, a timber staging 300 ft. in length

FIG. 3.—VIEW OF HEYSHAM HARBOUR, SHOWING GOODS SHEDS AND PASSENGER STATION TO THE RIGHT.

has been constructed to accommodate the fish traffic, and at the landward end of the same side is a 900-ft. length of concrete quay, at which may be berthed vessels engaged in pig-iron, timber, slate, and similar traffic. Ample sidings are provided here, backed by a spacious stacking ground for merchandise not requiring cover. In the bend of the harbour it is intended later to put in a grid-iron, by means of which vessels may be floated on at high tide and painted, etc. The greater part of the south side of the basin has been reserved for dealing with the passenger and cattle traffic, for which purpose a 1,600-ft. length of timber staging has been erected in three tiers at the various heights of 12 ft., 24 ft., and 36 ft. above low-water ordinary spring tides respectively. One or other of these stages will thus be available for landing at any state of the tide which ranges over 27 ft. From the landing stages passengers are conveyed to ground-level by electric lifts, adequate stairways having also been provided.

Crossing the goods shed by means of closed-in overhead gangways, the passenger station is reached. This is of the island platform type with accommodation, including refreshment rooms of the most commodious description. The platform is 600 ft. long by 47 ft. wide, and is completely covered in for about three-quarters of its length.

A feature of particular interest is the facilities afforded for the convenient handling of horse, cattle, pig, and geese traffic. After landing direct on to the stages, without the use of slings, the cattle are taken by underground passages and sloping ways to docks, pens, or lairs, or to extensive paddocks (including several for geese), in which they can recuperate after the voyage before going on by rail. The appreciation of the fact that cattle are greatly improved for market by being thus rested, and the provision of the necessary facilities is characteristic of the thorough manner in which the Midland Railway Company handle anything they undertake.

Two large goods sheds have been erected alongside the landing stages, on the girders of which travel several 5-ton electrically-driven overhead jib-cranes for dealing with the cargo. Similar cranes have been provided at the north wharf. Ample railway sidings have been laid down, all of which, together with the double passenger line, are

FIG. 4.—VIEW OF HEVSHAM HARBOUR, SHOWING ENTRANCE TO PROPOSED DOCK.

in direct communication with the main line at Lancaster.

Referring to the illustrations. Fig. 1 is a general plan from which may be gathered the general disposition of the works It will be noticed that a large area has been reserved as a site for a proposed dock, which will be completed at a later date. The entrance has, for the present, been closed by a brick coffer-dam, in which sluices have been fitted to drain away any water that may be accumulated.

It will thus be possible to carry out the work entirely in the dry, thus saving the additional expense that would have been incurred had all the work been carried out at the same time.

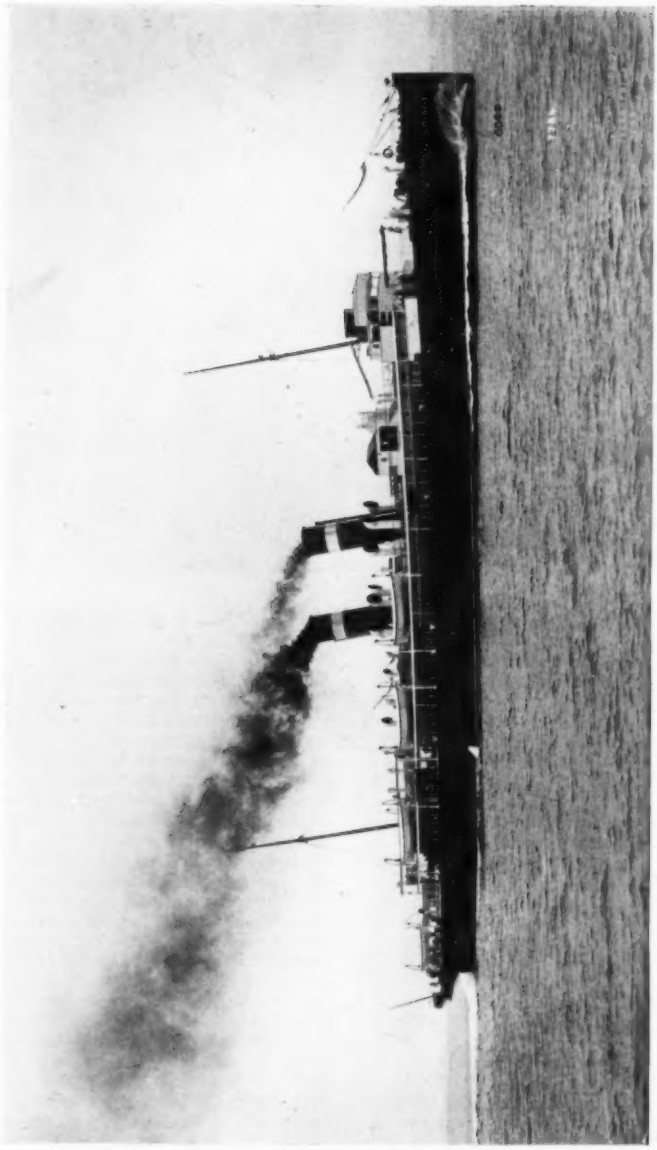
Fig. 2 shows the harbour entrance and roundheads.

Figs. 3 and 4 are contiguous views, and together give a panoramic view of the harbour.

The equipment of the harbour is of the most modern description, current for both lighting and power being supplied from a large power station which the company have put down.

We may conclude our notice by a brief reference to the four new vessels that have been specially built for this service from the designs of the company's naval architects, Messrs. Biles, Gray & Co. That forming the subject of the illustration, viz. *The Donegal*, may be taken as a typical example.

She is claimed to be one of, if not, the fastest steamers on the cross-channel service. Her principal dimensions are 330 ft. by 42 ft. by 18 ft. to upper deck, and 25 ft. 6 ins. to promenade deck. She is built of mild steel to scantlings approved by Board of Trade, and is amply sub-divided by water-tight compartments so as to ensure safety. The electric-lighting installation, which is on the single-wire system, is supplied with current by duplicate sets of turbo-electric generators. The vessel is ventilated on the thermo-tank system, which secures a supply of suitably warmed air, driven by electric fans through trunks to all compartments of the vessel. The first-class accommodation is situated amidships, with the third-class between the main and mizzen hatchways, while accommodation is provided for drovers at the after-end of the vessel. Above the promenade deck amidships there is a shade-deck, which forms an airy promenade for first-class passengers in fine weather and shelters the deck below during rain. From the shade-deck a large companion leads down to the first-class accommodation on the promenade



THE SS. DONEGAL, ONE OF THE NEW FLEET OF STEAMERS FOR THE MIDLAND RAILWAY COMPANY'S HEYSHAM–BELFAST SERVICE.

deck. This accommodation consists of private cabins having one, two, and four berths. Abaft the large vestibule is the smoking-room. On the upper deck are one, two, and four-berth cabins, and on the port side is a ladies' room, with a dado of waxed oak, the upper portion of the sides being in Tynecastle tapestry finished ivory-white. Abaft this are several ladies' state-rooms.

The dining-saloon is lighted by round lights, framed in wheel design, and enriched with carved ornament. The sides are of Tynecastle tapestry, decorated and finished ivory-white, while the ceiling is of a small pattern tapestry to match; the sideboards and other furniture are of waxed oak. A feature of this apartment is a tiled fireplace in antique copper, with curbings and mountings to match. The upholstery is in vermilion tapestry, the floor being laid with Brussels carpet, and the windows curtained with silk tapestry of the same colour. The saloon is additionally lighted and ventilated by an overhead trunk, surmounted by a domed skylight glazed in rough plate-glass stained with a *fleur-de-lys* diaper, this being the *motif* of the decorative design. Where this trunk passes through the vestibule the sides are filled with leaded-glass panels, representing ancient vessels of the Viking type. The accommodation for third-class passengers marks a considerable advance on the ordinary Channel steamer, there being a number of separate four-berth state-rooms, in addition to a large saloon.

It only remains to be added that new fast passenger and goods services in connection with the sailings have been arranged from and to London and all principal towns served by the Midland Railway, commencing September 1st.

Birmingham Welsh Waterworks.

ONE of the most interesting and noteworthy events that has happened since the appearance of the last number of this paper, was the inauguration of the new Birmingham waterworks by his Majesty the King.

After over ten years' work and the expenditure of nearly six millions sterling, the town of Birmingham will now be in possession of an ample supply of Welsh water. Hitherto the supply has been derived from deep wells and local surface sources, but the rapid growth of the population compelled the city council to look beyond their immediate district for supplies; and at the suggestion of the engineer, Mr. James Mansergh, F.R.S., in whose mind the idea was first conceived over forty years ago, not much difficulty was experienced in adopting his suggestion of utilising the water-shed of the rivers of Mid-Wales. A Bill was accordingly promoted in Parliament for bringing water from Wales, and after the customary opposition which such schemes find from various interested persons and authorities, it received the Royal assent on June 27, 1892; and in October of the same year, Mr. Mansergh was instructed by the City Council to prepare the necessary plans and proceed with the work. The gathering ground is situated partly in the counties of Brecon and Radnor, and contains 45,562 acres, or 71 sq. miles, with an elevation varying from 700 ft. at the bottom of the lowest dam to 2,100 ft. above the sea-level.

This area forms the watershed of the rivers Elan and Claerwen, and consists mainly of sparsely populated mountain-land.

The average rainfall calculated from observations spread over a period of years is about 66 ins. per annum, of which it will be possible to collect, making the necessary allowances for dry seasons and evaporation, nearly 40 ins. This quantity is subject to deduction for the necessary water of compensation, amounting to 27,000,000 gals., which has to be supplied to the River Elan, and will leave available for the Birmingham supply 75,000,000 gals. a day, which is calculated to suffice for all requirements during the next fifty years. Analysis has shown the water to be very soft (1·8 degs.), practically free from animal pollution, and from nitrates and nitrites, while the total solids per gallon do not amount to more than 5 grains.

The selection of a watershed suitable for the supply of Birmingham was specially difficult in view of the considerable elevation of the city. The supply water is turned into the aqueduct at 770 ft. above sea-level, and the point of delivery at the Frankley end of the aqueduct, 7 miles from Birmingham, is 600 ft. above sea-level, the water travelling by the natural process of gravitation through the whole 73 miles of the journey.

The works on the watershed consist of six reservoirs, three of which are situated in the valley of the Elan, and are formed by masonry dams erected in suitable positions and at successive levels varying in height from 98 ft. to 128 ft. above the river bed. Those on the Elan are completed; the other three, in the valley of the Claerwen, have yet to be erected. Their main dimensions are given in the table overleaf.

The lowest dam, that at Caban Côch, is about ¼ mile below the confluence of the two rivers, and will back the water up the Elan valley 4½ miles, and up the Claerwen

	Capacity in Million Gallons.	Height of Dam above River Bed.	Length of Dam.	Height of Top of Water above Sea-level.	Top Water Area.
Caban Côch	7800	122	600	832	500
Pen-y-Gareg	1320	123	525	945	124
Craig Goch	2000	135	580	1040	217
Dol-y-Mynach	1680	101	938	900	147
Cil Derwynt	3100	109	1050	1095	300
Pant-y-Beddau	2000	98	720	1175	240

2⅛ miles. From Rhayader station to the head of the dam at Craig-Goch is a distance of 10 miles. Along this part of the water-shed the Corporation built a railway for the purpose of bringing up material, stores, etc., from the Mid-Wales line at Rhayader with which it forms a junction.

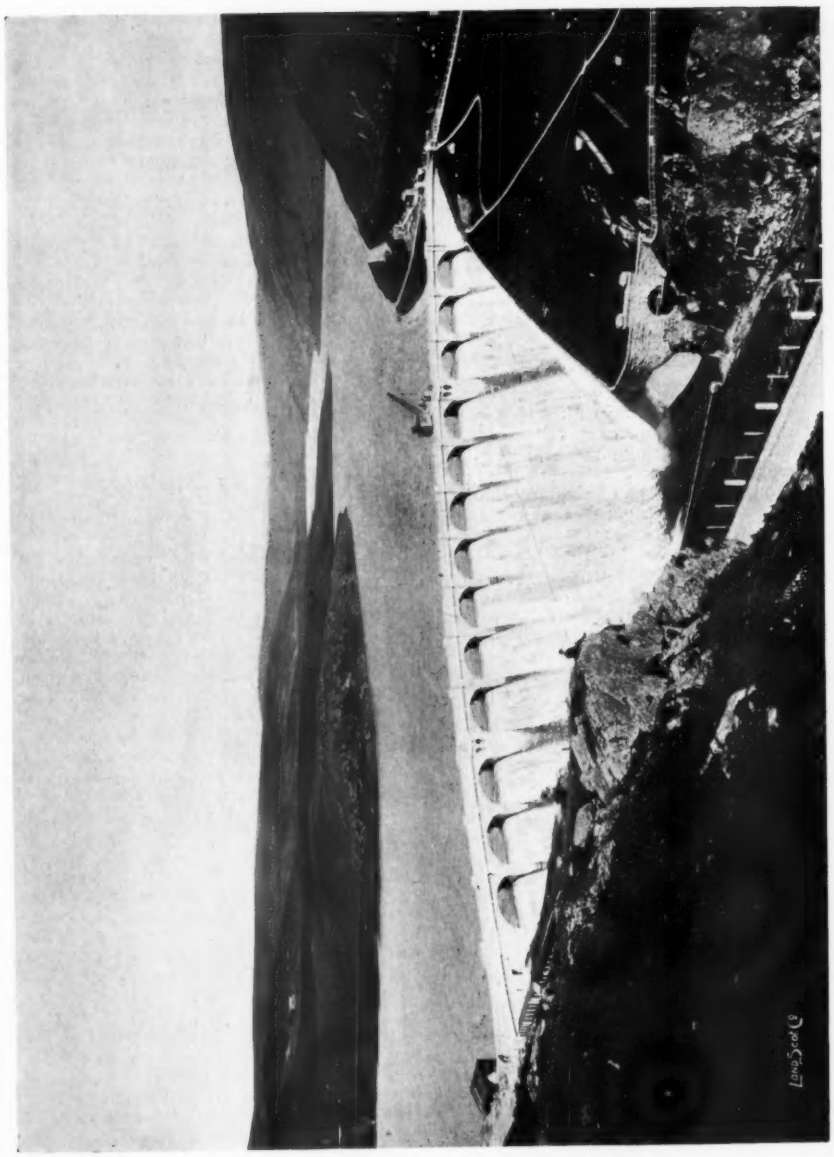
In addition to the six dams mentioned above there is another extending to within 40 ft. of the top of the surface water of the Caban Côch reservoir, which it divides. Its function is to hold the water up in Caban Côch reservoir to a sufficient height to fill the aqueduct inlet which is 770 ft. above sea level, the bottom of this dam being 700 ft. When the reservoir is drawn down during a drought the 40 ft. of water above the top surface of the dam will be used for both compensation and Birmingham supply services, the remainder being retained for the compensation water only while the Birmingham supply will be turned into the aqueduct from the upper reservoirs by the submerged dam.

As regards the construction of the dams themselves the hearting consists of Cyclopean rubble in concrete, with rather more than half the mass solid stone, faced with square stone blocks varying in weight up to a maximum of 10 tons. The walls are on the inside, vertical for the most part, finishing with a slight batter at the top; on the outside there is a curved batter of 1 in 2, finishing in a reverse curve. In the Caban Côch the lowest dam, a culvert at river level has been put in, which contains the valves and pipes through which the compensation water passes. The Pen-y-Gareg or second dam, is situated 4¼ miles above Caban Côch, and backs the water up the valley for a distance of 1½ mile. An 18-ft. culvert penetrates the middle of the dam in the old river-bed, and is fitted with a steel buckhead for decanting the water through to the lower reservoir. A valve-tower has been constructed from the level of the culvert, valves admitting water to a vertical pipe being provided so that decantation may be effected at various levels.

The highest dam is the Craig Goch, an illustration of which is given. This is a very handsome piece of masonry, and forms a reservoir 2½ miles in length.

Water is decanted from this reservoir, through a valve-tower placed in the centre of the dam, to a tunnel which communicates between this and the lower reservoir.

A tunnel, 2,380 yds. long, connecting Caban Côch reservoir with the filter-beds forms the first portion of the aqueduct to Birmingham. A series of 30 filter-beds are to be constructed, but the whole of these are not yet completed. This part of the scheme was determined upon in consequence of the experience of Liverpool, which showed that the discharging capacity of the lines of iron pipes was liable to serious diminution in consequence of the growth which formed and caused a deposit in the pipes. As the experience of Liverpool proved that the growth which caused the trouble was removed from the water in the process of filtration, it was decided to undertake the provision of filters at the head of the aqueduct. From this point the water will be conveyed to Birmingham, a distance of 73⅓ miles, by means of tunnels through the hills, and cut and cover work over the levels, whilst iron pipes will be used in crossing the valleys and rivers. There are about 13½ miles of tunnels, 23 miles of cut and cover, and 37 miles of iron pipes. The cut and cover and tunnels are 8 ft. in diameter, and the iron pipes 42 ins. in diameter. From the reservoirs at the gathering ground the conduit passes a little to the south of Rhayader and near Knighton, Ludlow, Cleobury Mortimer, through the Wyre forest, then by way of Kidderminster, Stourbridge, and Hagley, on to Frankley reservoir 7 miles from Birmingham. There is also a service reservoir at Northfield, near to the Birmingham end. The conduit crosses the Wye a little south of Rhayader, the Ithon and four of its tributary streams; the Teme three times; two tributaries of the Teme; the Severn to the north of Bewdley, and the Stour and one of its tributaries. The rate



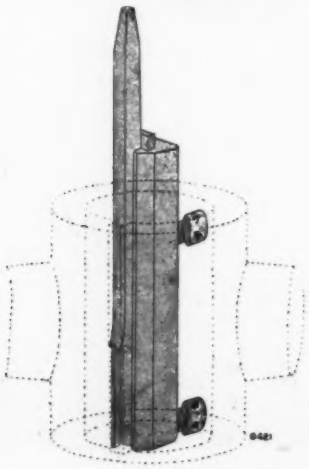
BIRMINGHAM WELSH WATER SCHEME. THE CRAIG GOCH DAM.

at which the water will travel from Wales to Birmingham is rather less than 2 miles an hour, and any given portion of the stream in the conduit will therefore complete its journey in a day and a half. The works in the Elan valley, with the exception of the first length of railway, which was constructed under contract, have been executed by workmen employed immediately by the water committee, without the intervention of a contractor.

The whole of the work was executed under the supervision of the engineers Messrs. James Mansergh and Sons, to whom and to *Engineering* we must express our acknowledgments for the information regarding the scheme and works.

Brazing Cast-Iron.

THE operation of burning fractured castings is one that is always attended with great risk, and therefore cannot be recommended when the casting must bear weight, or where there is a probability of stress in any direction. A broken casting frequently causes considerable delay, unless something can be satisfactorily done to repair the break. This result is claimed by Herr Pich, the inventor of "Ferrofix," the name given to a compound consisting of a metallic oxide and a liquid which is placed over the surfaces of the fracture, and is then heated to about 1,800 degs. Fahr. In conjunction with the mixture boric acid is used as a flux, a sufficient quantity of the mixture being heaped over the joint to ensure its covering every part, the melting causing it to permeate the iron to the depth of an inch. This is done by the displacement of the carbon and the filling of the interstices with the metal; but, as in the burning of cast-iron, great care has to be exercised to prevent the starting of a fresh fracture. We have seen a couple of illustrations showing the repair made on a large belt pulley section—weighing about three tons—broken through the arm, and the repair of a pump casing. About the first-named we are rather sceptical, as it presents something which does not admit of patch-work, and would be immediately condemned in good practice, although it is said that the joint is from five to ten per cent. stronger than the adjacent metal. In the second case it was used more in the form of a metallic filling, and in that capacity we should be willing to admit its utility.



NEW KEYWAY SLOTTER.

New Keyway Slotter.

MESSRS. RIMINGTON BROS., of Carlisle, have recently introduced a keyway slotter, "The Deadfit," which we think will prove a very valuable accessory to the fitting shop. It consists of a vertical guide, which is inserted in the piece to be slotted, and held in position (as shown in the illustration) by the screws behind. The slotters are made in various sizes, to accommodate holes from $\frac{11}{16}$ in. to 18 ins. diameter, with a width of keyway from $\frac{1}{4}$ in. to 4 ins. Special sizes of slotters are also supplied, but by the insertion of extra packing behind the screws the ordinary sizes can be adjusted to suit almost anything. The tool is made of square section steel, machined to fit the groove in which it slides, and tapering at the top to form a chisel-head. The bottom end is slightly in advance of the straight face, and forms the cutting part of the drift. It is further relieved at the back to allow clearance for the chippings, the bottom end of the tool being left longer to form a heel, which comes to a stop before the cutting edge has quite penetrated the work. This prevents the bottom edge of the slot from being torn as the work is moved over the edge of the block, and the drift is then driven through by a few gentle blows. The succeeding cuts to the required depth are made by packing strips used in rotation after each cut. For keywaying large pulleys, screw-propellers, or in the larger sizes of slots, a number of narrow cuts are first taken, and finally finished to size by the full width of drift.

ABSTRACTS.

Mechanical Draught for Boilers. **Walter Yates, M.I.Mech.E.** It is unnecessary for practical purposes to estimate to a nicety the weight of air necessary for the combustion of fuel, for the variableness in the combustion renders all ordinary calculations approximate only. It is, therefore, the common practice to estimate the amount chemically required for coal at 12 lbs. or say 150 cub. ft. per lb. of fuel. It is found, however, in practice, that the chemical requirement is very much below that actually needed for complete combustion, due to causes which it is unnecessary to enter into here, and it is customary to provide for double this quantity, or 24 lbs. of air per lb. of fuel, where natural draught is to be used with hand-firing. With mechanical draught, however, this excess of air over the chemical requirement is much reduced, becoming about 18 lbs. of air per lb. of coal. Natural draught is that produced by a chimney. The only openings to a chimney should be at either end of it. Leakage of air through a chimney or boiler setting has a very serious influence on the draught, and is often accountable for a very greatly decreased efficiency; not only is this the case with faulty brickwork, but it takes place where the mortar joints are apparently sound. The effect is, of course, to increase the volume of air to be handled and decrease the temperature, resulting in a reduction of the draught in the chimney. Draught is caused by the superior weight of a column of cold air over the weight of a similar column of equal height of the hot air enclosed in the chimney. A chimney with natural draught will have a draught dependent upon its height, the power of which will not vary, except upon the rise or fall of the internal temperature. It has, therefore, no sucking power; in fact, the term suction in this connection is a fallacy. The chimney acts because the external air is heavier than the internal, and thus presses into the chimney by the only available opening—viz., that at the bottom, the furnace front. The pressure or intensity of the draught fixes the amount of fuel it is possible to burn on a given area of grate. It therefore becomes necessary, when it is desired to increase the steaming capacity of a boiler by increasing its coal consumption, to increase the intensity of the draught, and the only way in chimney draught is to increase the temperature of the gases passing up it, or increase the height of the chimney. The first method, of course, means a large amount of waste, and is a very uneconomical arrangement; the second is expensive and unusual. A chimney stack 150 ft. high will burn from 15 lbs. to 20 lbs. of coal per square foot of grate area per hour under normal condititions, but in wet or foggy weather it will be very much less than this, as the wet air is lighter than the dry, and thus produces less pressure at the furnace (the weight of water vapour is about half that of air). A fair average of temperature in the furnace is 2,400 degs. Fahr., and that of the escaping gases at the chimney, without economisers, 600 degs. Fahr. This means that one-quarter of the total heat generated is sent up the chimney to waste. Thus, on a 2,000-h.p. plant, almost 500 h.p. is going up the chimney per hour, and the coal bill necessary to sustain this will come to a big figure in the year. Suppose we could reduce the amount of air accompanying each pound of coal from, say, 24 lbs. to 12 lbs. (the chemical requirement), and the temperature kept the same, then we would only send $\frac{1}{2}$ of the total power up the chimney and save $\frac{1}{2}$ of the coal bill at the same time. The temperature in the furnace would then be greater, the heat generated greater, and, of course, the temperature of the gases at chimney less. The effect of the draught and the air supply to boilers having been demonstrated to be of such importance, we are brought now to the consideration of the best means of producing the requisite draught, and it is only the author's contention, but it has become a well ascertained fact, that it is cheaper and better in every way to provide the necessary supply of air for burning fuel in steam boilers by mechanical means, and to take as much heat out of the hot gases after they have ceased to be in contact with the boiler itself before they are turned out into the atmosphere, than to do it in the older way by utilising a portion of the heat generated to create the necessary supply of air. This is the primary reason for using a mechanical means of moving the air. The heat previously necessary to create the draught by means of a chimney may now be employed usefully in other directions. There are several forms of mechanical draught, and perhaps the first step in that direction is the use of steam jets. But it is with fan-draught that this paper is intended more particularly to deal. Fan-draught may be divided into two distinct classes—viz. forced and induced. Forced draught may, again, be subdivided into two methods—viz. first, closed stokehold, and second, closed ash-pit. The first, or closed stokehold method, is almost exclusively used for ship work. For land work or stationary boilers, however, this method can scarcely ever be adopted; and if a forced-draught system is desired, the closed ash-pit must be resorted to. As in the stokehold method a minimum fan-power is

required, as cold air is being handled, but there are several disadvantages which, in the author's opinion, far outweigh any saving which might be effected by using the smaller fan, as for instance—(1) Initial cost of furnace fronts is very high, say £16 per furnace, and these are frequently needing repair. (2) Fires do not burn so evenly. (3) The air supply must be shut off before the fire-door is opened, or the stoker would run grave risk of being burned through the pressure forcing the heat and flames outwards. (Automatic appliances have been tried, but are not always a success.) (4) The pipes conveying the air to the

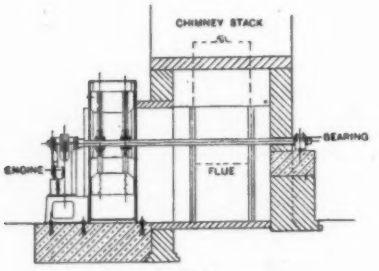


FIG. 1.

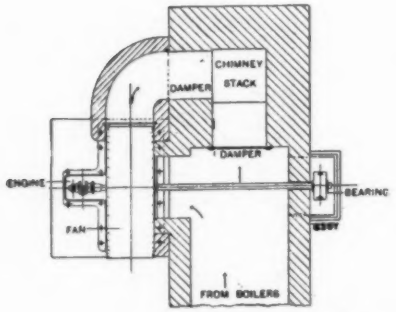


FIG. 2.

FIGS. 1 AND 2.—MECHANICAL DRAUGHT PLANT FOR BOILERS.

furnaces are very much in the way, and are usually very unsightly. In the author's opinion, by far the best method of obtaining draught by mechanical means is the induced-draught system, wherein the fan is placed between the boilers and chimney, or point of discharge of waste products into atmosphere. By such an arrangement the coal consumption may be increased from the 15 to 20 lbs. per sq. ft. of grate per chimney-draught to 30 to 40 lbs per ft. under ordinary conditions, and beyond this amount under special circumstances. This results not only in a proportionate increase of steaming capacity in the boilers, but in greater efficiency of combustion, and consequent economy. Most steam-boiler plants nowadays are provided with economisers. Where such is the case an opening is made in the flue between the economisers and chimney, and the fan inlet connected thereto by a short brick or metal flue. Another opening is made in the main flue at a point nearer the chimney, or into the chimney itself, and this openining is connected to the fan outlet in the same way as to the inlet. Between the openings, and inside the main flue is placed a damper, so that all gases after leaving the boilers must of necessity pass through the fan on their way to the chimney, so long as the aforementioned damper is closed. It is also customary to place dampers both at the inlet and outlet of the fan, so that by manipulating these two and the one in the main flue, the fan may be cut out, and natural draught resorted to in case of necessity. The same arrangement applies where no economisers are installed, and in such cases the fan handles the gases at the high temperature at which they leave the boilers. Of course in either case special arrangements must be made in order to keep the bearings cool, either by water-jacketed bearings or an arrangement of air-cooling One installation is illustrated by Figs. 1 and 2, which show elevation and plan respectively. In this instance the fan inlet is placed close against the main flue, and again the outlet or delivery is through a connection into the chimney. It will be noticed that the fan-shaft goes right through the flue to a bearing on the opposite side. This was necessary as the fan is a large one, and an overhung wheel was not desirable. This plant showed a saving of exactly 25 per cent. of the year's coal bill, through being enabled to burn an inferior quality of coal. This saving more than paid for the induced-draught plant in the first year's run. The author describes several methods of installing fans, and proceeds to remark that the very satisfactory results secured by a system of induced draught are due to a less volume of air being required, though at a higher pressure than with chimney draught. A chimney usually works at a vacuum of $\frac{1}{2}$ in. to $\frac{3}{4}$ in., while an induced fan is generally arranged to give $1\frac{1}{2}$ in. to 2 ins. In consequence of this thicker fires can be carried, and higher temperatures maintained, resulting in more rapid conduction of heat through the heating surface, and therefore a greater economy of heat than with chimney draught. This high temperature of combustion, and consequent increase of evaporating power of the boilers, is such that usually three boilers, with induced draught, will do the work of four with chimney or natural draught. Occasionally better results even than these have been secured. One advantage of induced over-forced draught is that a better and more even distribution of air is obtained. One of the best arguments in favour of induced draught is that by it the pressure may be kept practically constant, and consequently the temperature, so that the boiler shell and furnaces do not contract and expand to the same extent, thus saving large sums of money in repair bills for leaky joints and rivets. It is not always possible to keep boilers idle when an induced-draught system is introduced to an existing plant, as where one or

two boilers may be installed. In such a case an alternative is to reduce the length of the fire-bars, and by keeping thicker fires to secure the beneficial results already described. One of the most valuable features of an induced-draught apparatus is that it enables the high temperature upon which a chimney depends for its results to be dispensed with. In fact, the more heat abstracted from the gases by economisers and suchlike apparatus for heating water, air, etc., the better it is for the fan. A very important point not yet touched upon, and particularly applicable to buildings projected, is the question of the chimney in relation to induced draught. A stack higher than that necessary to carry the gases above the surrounding property, say about 50 ft. high, is useless where an induced-draught fan is at work. It therefore pays to consider the question of fan *versus* chimney in the matter of first cost, and also as to economy of space.—*Paper read before the Inst. of Heating and Ventilating Engineers, July 21, 1904.*

Design and Test of a Steam-power Plant. **E. G. Hiller, M.I.Mech.E.** In view of the interest excited at the present time by the composition of the gas-engine and the steam-turbine in power production, particulars of the construction and test of a modern factory steam-plant which has been designed with the object of obtaining good commercial economical results will be interesting. By commercial economical results is meant, that the object in view was not simply to obtain an engine which would use the smallest number of pounds of steam per i.h.p. per hour, but one which would, taking account of the capital, maintenance, fuel, water, and other incidental expenses, produce the power required on the fly-wheel at the lowest total cost for steam plant. This plant has now been running for about twelve months at some mills at Bessbrook, co. Armagh. The specifications and general design of the plant were prepared by the Consultative Branch of the National Boiler and General Insurance Company. The most suitable site for the new engine was on the side of the mill furthest from the present boiler-house, and, consequently, an exceptionally long steam-pipe range was necessary. Due account had to be taken of the high price of coal at Bessbrook (which may be taken approximately at 16*s.* per ton), the necessity for avoiding breakdowns, the isolated position of the mills in the country, and their distance from any large engineering centre, where, in the event of breakdown, skilled workmen could be readily obtained. It was decided to have the engines of ample power in order to allow for any subsequent extensions. The engines were therefore constructed to develop, if necessary, under regular work at least 1,500 i.h.p. without material falling off in economy. The plant consisted in the following:—Three Lancashire boilers, 8 ft. by 30 ft., at 160 lbs.; two boilers being required for the load, the other being a spare. One Green's fuel economiser, 224 pipes. Three Musgrave & Dixon superheaters, one to each boiler, 217 sq. ft. heating surface each. Ten-inch main range steam pipes. Four-inch feed ranges. One Weir feed pump. (Standby.) 1,200 i.h.p. Cross compound engine, 25-in. and 52-in. cylinders by 5-ft. stroke, working at 25 revolutions. The feed-water for the boilers is taken from the discharge of the jet condenser; it is then pumped into the economiser and passed through it into the boilers. The steam passes from each boiler through the superheater in the downtake flue, at the back of the boiler, and thence to the main steam range, by which it reaches the engine. The cyliners are unjacketed. The high-pressure cylinder is supplied with superheated steam, and a reheater is fitted to heat the low-pressure cylinder steam supply. Tests made on the plant showed the following results:—

	No. of Test. First.	Second.	Third.
Heat supplied per minute i.h.p. ... B T.U.	216·85	217·15	222·95
Thermal efficiency, per cent.	19·56	19·53	19·02
Efficiency ratio	0·700	0·703	0·667
Pounds of steam used per i.h.p per hour	11·10	11·24	11·59
Coal fired per i.h.p. per hour	1·48	1·44	—

In the above calculations the specific heat of the superheated steam has been taken at 0·6. The average weekly coal consumption for the quarter following—namely from the week ending June 20th to the week ending September 26th—a period of fourteen working weeks, was 42·2 tons. This total weekly coal-consumption agrees well with the results of the tests as follows:—

	Tons.
Total coal used by engine for driving load during 55 hours per week at 1·48 lbs. per i.h.p. per hour, and 981 h.p. as per test results	35·6
Banking coal	6·6
	42·2

The amount of banking coal, in view of the fact that the firm let the fires out entirely at the week-end, is not excessive. The contract for all the engineering work was let in one sum to the general contractors, but the sub-division of the cost of each section is about as follows:—

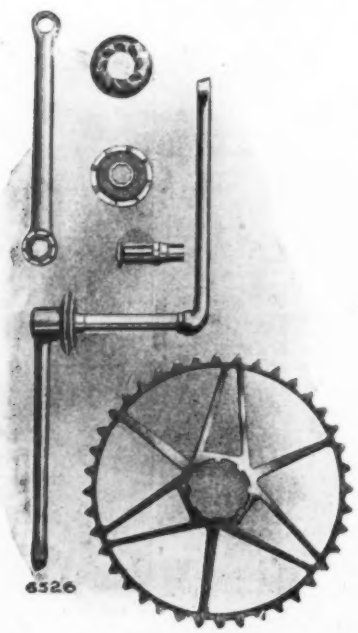
	£
Engine complete, 25 ins. and 52 ins. by 5 ft. 0 in. cylinders	5,875
Three boilers, 8 ft. 0 in. by 30 ft. 0 in. ...	1,840
Steam and feed-pipes, pumps and valves ...	865
Economiser, 224 pipes with details	396
Three superheaters with cast-steel boxes ...	332
Sundries and travelling crane	332
	£9,660

In addition to the above, the mill-gearing alterations cost about £2,740. This formed a large proportion of the total cost, but the subsequent running of the whole of the shafting under the smooth, steady rope-drive has been found of the greatest advantage in the mill and to be well worth the additional expenditure which was necessary to secure this result. The cost of the substantial granite engine-house the firm preferred to erect, with the new rope-race walls and the boiler-house alterations, was about £5,000. The total gross cost of the new scheme, therefore, including a bonus paid to the engine-builders, may be taken as about £18,000. A careful examination by the firm of their subsequent annual running charges and other items effected by the alterations has

shown a decrease per annum of about £3,000. This large reduction sufficiently shows that the new plant was well justified, but it may be interesting to note that this gain is not solely due to coal saving, but to other important items as follows :— Coal reduction in the h.p. and l.p. batteries of boilers due to the change, 2,000 tons at 16*s.*, £1,600; reduced labour in boiler-house, £75; reduced labour in repairing old gearing, £150; reduced oil and stores, one engine instead of three, £155; reduced charges for wheels and breakages, etc., £250; estimated value of steadier turning in shed and factory, £670; and value of floor space, due to vacant engine-houses to be used for looms, etc., £100. The analysis of running costs per i.h.p. per hour for 2,800 working hours per year and for 1,000 h.p., are as under :—

	Annual Cost.	Pence cost per i.h.p. hour.
Coal for engine and banking, 2,000 tons at 16*s.*	£1,600 ...	0·1370*d.*
Stokehole labour	120 ...	0·0103
Engine-house and rope-race labour	120 ...	0·0103
Oil and stores for all plant and rope-race	110 ...	0·0094
Upkeep and minor repairs and insurance	110 ...	0·0095
Water free	—	—
	£2,060	0·1765*d.*

At 1,000 h.p.—cost per i.h.p. per annum—£2. If coal had been at 8*s.* a ton, as in many places in England, then the total costs would be £1,260 per annum, or 0·108 pence per i.h.p. hour, or cost per i.h.p. per annum, £1 5*s.* In the design of steam-engines for driving economically regular loads the practice hitherto has varied. In some cases pressures as high as 200 lbs. per sq. in. have been utilised with triple-expansion engines, both with and without steam-jacketed cylinders. The triple-expansion engine designed with steam jackets is a very complex and expensive machine. The results of the working of the Bessbrook engine, and other engines of similar design, show that high economy is obtainable with a compound engine free from the complications and difficulties resulting from the use of three cylinders with steam jackets.—*Proc. Inst. Mech. Eng., July 22, 1904.*



CRANK AND CHAIN WHEEL.

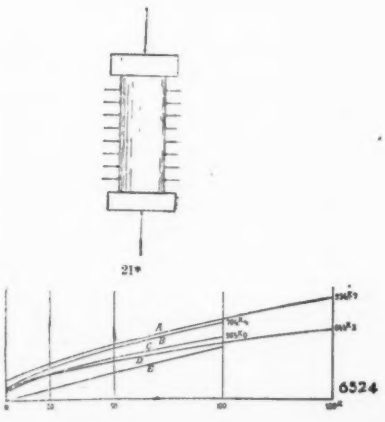
A Factory Research Laboratory. **Anon.** This article gives an account of the methods of research employed in the factory of the Rudge-Whitworth Company at Coventry. All the materials of construction are submitted to rigorous tests—analytical and physical. The percentage of sulphur in steel is found by dissolving a certain quantity of the steel, in the shape of drillings, in pure dilute hydrochloric acid, the gases given off being passed through a series of **U** tubes containing sugar of lead in solution. The sulphuretted hydrogen given off turns this solution black, first in the first tube, then in the second, and so on, the quantity of solution in each tube and the quantity of drillings being so fixed that each **U** tube which is turned black denotes ·01 per cent. of sulphur in the steel. For example, if three tubes are completely changed, and if the fourth is about half turned, the percentage would be ·035. The percentage of carbon in steel is determined by acting on a given weight of steel by a solution of copper sodium chloride, which dissolves the steel and leaves the carbon in suspension. The particles of carbon are collected by filtering, and are strongly heated in a tube containing copper oxide, through which oxygen is passed. The carbon burns, forming carbonic acid gas, which is passed through a **U** tube containing caustic potash. The gas is absorbed by the potash, and from the increase in weight of the **U** tube the percentage of carbon can be deduced. A shorter method is to act on a given weight of steel, and on an exactly similar weight of a steel whose composition is accurately known, with equal weight of nitric acid. A coloured solution is formed, the depth of colour depending on the amount of carbon present. The solutions are poured into two graduated tubes, the level of the solution of the steel whose composition is known being opposite the graduation corresponding to the percentage of carbon present. Water is then added to the other tube until the two solutions appear to be identical in colour, when the height of the solution gives, by its corresponding graduation, the percentage of carbon in the specimen under examination. An even quicker method used is to make a section suitable for examination by the micro photographic method. Micro-photography is also used as a means of examining the condition of nickel-plating and enamelling. Cycle enamels are tested by taking

lengths of cycle tubes and exposing them simultaneously — some to a hot, moist atmosphere, others to dry atmosphere, cold, moist atmosphere, and to water, the results being noted by the aid of the microscope. A special tensile testing machine is also used for determining the quality of strips cut from completed tyre covers. As an illustration of what may be accomplished in the improvement of a design by the use of scientific methods of testing, the evolution of the aëro special gear is interesting. The object was to obtain a lighter gear without sacrificing strength or durability. The gear complete was first placed in a bottom bracket holder, bolted down to the bed plate of a Denison testing machine, and one pedal being fixed, an increasing load was applied to the other, the deflection and persuant set being recorded in each case. A length of bicycle chain was then placed round the chain wheel, a weight of 20 lbs. was attached to the pedal pin, and the chain wheel was given a rapidly alternating motion of oscillation, the number of oscillations being about 100 per minute, the crank being thus subjected to a series of opposite stresses, rapidly repeated. Different types of crank arm and of fastenings for the chain wheel were tried in this way, the type finally chosen being shown in the Fig. Here, although the weight is 25 per cent. less, the strength is 50 per cent. greater than in the original pattern. — *The Engineer*, *Vol.* 97, *No.* 2529, pp. 607–608. — *A. H. G.*

Influence of Lateral Pressures on the Crushing Resistance of Solid Bodies. **M. Considère.** The author, in a previous paper, enunciated the following proposition: The crushing of a solid body cannot be produced without a transverse bulging taking place. In order, therefore, to resist the crushing effect, the bulging tendency should be acted against, a hooping arrangement being one of the means available. Many experiments have been made on mortar or concrete prisms, in which, close to the surface, metal coils had been embedded, the windings of which were so near to one another as to exert a pressure on the core as soon as the latter showed a tendency to bulge out. The results obtained in this connection are as follows: If C be the natural resistance to crushing of the mortar used, and P the pressure per unit of lateral surface exerted by the hooping at a given moment on the core it encircles, the resistance per unit of surface offered by the hooped prism to crushing will be $1{\cdot}5\,C + 4{\cdot}8\,P$. In addition to the bearing these results have on structural work, they are interesting also from the point of view of the general properties of solid bodies. The author therefore undertook a confirmation of these results by another kind of experiment, the more so as his former tests were confined to narrow limits of pressure. In the first place, impermeable mortar cylinders immersed in water were exposed to pressure; these included 300 kg. to 600 kg. of cement per cubic metre of sand, and were 10 to 126 days old. With a diameter of 30 mm. the relatively considerable length of 80 mm. was chosen, so that the resistance of the cylinders in the middle of their length might be independent of the variable friction of the bases on the compressing cushion. In order to obtain a pressure of the surrounding liquid equivalent to a hooping effect, the liquid must not penetrate into the mortar. The rough surfaces of the cylinders were therefore coated with three thin cement layers and a layer of wax, so as to render them impermeable. Each cylinder was placed on the bottom of the press-chamber and the piston put in contact with its upper surface, when the mortar enclosed in the press-chamber was compressed to the pressure required, and a pressure increasing up to the crushing of the mortar was brought to bear on the piston. The results of 65 experiments are recorded in the following table, averages being taken of the figures relative to the mortars of the same composition. Both the pressures and resistances are expressed per sq. cm.:—

Weight of Cement per cub. m. of Sand.	Age of Mortar. Days.	Resistance of Mortar immersed in Water compressed to				
		0 kg.	20 kg.	50 kg.	100 kg.	150 kg.
—	46	53·2	—	370·1	565·0	—
300 kg.	126	74·3	227·1	—	523·3	645·2
—	34	92·2	—	460·8	704·4	—
600 kg.	126	170·4	317·8	—	728·6	934·7

The results of these experiments are plotted in the four curves $A\,B\,C\,D$, drawn in full, the water-pressures being plotted as abscissæ and the

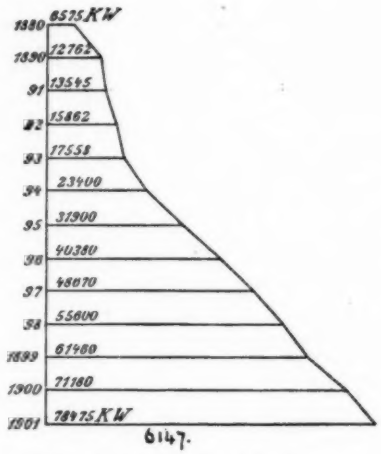


corresponding crushing resistances as ordinates. The straight line OE gives the values of the term $4{\cdot}8\,P$ —that is, the resistances which mortar cylinders devoid of any cohesion between the mortar grains would have given merely in virtue of the friction. The portions of the ordinates lying between the straight line OE and the curve $A\,B\,C\,D$ give accordingly the value of the increase in resistance produced by cohesion. The curves $A\,B$, and, to a certain extent, the curve C, agree very well with the formula alluded to above, whereas the curve D has an anomalous character, indicating a less rapid progress of the resistance. This departure may, however, be ascribed to a slight penetration of water into the pores of the cylinders, though any experiments where this was noted have been carefully excluded. The above rule should, however, be enunciated in the following modified form: "The crushing resistance of a prism, constituted by mortar of a proper resistance C, and being submitted to a pressure P over the whole of its lateral surface, is equivalent to $A\,C + 4{\cdot}8\,P$, the co-efficient A being equal to unity as the pressure P is *nil*, augmenting along with the latter and attaining for a pressure intermediate between 40 kg. and 50 kg. the value 1·5, which remains constant even for the highest pressures experimented with." The following general proposition may be stated for any kind of material: "The crushing resistance of a solid of a proper resistance P and an angle of friction f is equivalent to

$$At + \frac{P}{Ag^2\left(\frac{\pi}{4} - \frac{f}{2}\right)},$$

on a pressure P being brought to bear on its lateral surface. A is at least equal to unity." It should be mentioned that the ductility of mortars and concretes is about 20 times higher in the case of their being compressed in water submitted to pressure than if they are in the natural state. Some further experiments were made on a prism penetrated by water submitted to pressure, the prism being free from any wax coating. In the case of cylinders constituted by meagre mortar that were completely penetrated by the water submitted to pressure, the increase of resistance has been found equal to the pressure of the liquid, the phenomena observed being quite identical with those obtaining in the case of the liquid surrounding completely the molecules and compressing them in every direction. The principle of Archimedes is therefore true of the molecules of porous bodies as well as of the whole or of any fragment of these bodies. Cubes of cement dough were also tested, and the increase of their resistance found to be intermediate between those of wax-coated cylinders and those of very permeable mortars. The author hopes to demonstrate that the facts brought out by these experiments will allow of considerably reducing the dimensions used in connection with foundation work penetrating some distance into water or into the ground.—*Beton & Eisen, Vol. III, No. 3, 1904*, pp. 157, 158.—*A. G.*

State of Electrical Industry in Spain. **D. Blumenthal.** The fact that Spain uses electric



STATE OF ELECTRICAL INDUSTRY IN SPAIN.

lighting to the highest extent of all European countries, excepting Switzerland, is accounted for by the prohibitory cost of gas lighting—all the gas coal having to be imported from abroad. Fig. 1 gives a graphic record of the development taken by the consumption of electric central stations since 1878, when the first central station was put into operation. Since 1901 there has been a considerable further increase, so that 100,000 kw. would not now appear to be too high a figure, corresponding with about 5 watts per inhabitant; whereas about 1,000 central stations—out of which one-third are private undertakings—are being worked in Spain at the present moment. The development of electricity has been especially powerful in the capitals, Madrid and Barcelona, where German firms (Allgemeine and Schuckert) first undertook the problem of providing electric power; the direct-current 3-conductor system at 2 × 110 volts being mostly used. The electricity works of Madrid are installed according to the most recent requirements, comprising a total output of machines as high as 16,600 kilowatts and 17,700 kilowatts of secondary batteries, corresponding with 66 installed watts per inhabitant, as compared with 48 watts per inhabitant in Berlin. The immense amounts of water-power have been utilised to an ever-increasing extent for about 10 years, so that electric light has found its way even to the house of the poorest man. These hydraulic central stations are mostly alternating-current plants serving, in most cases, to supply quite a number of localities with electric energy. In order to be superintended even by unskilled persons, they are devoid of any complicated switching and regulating apparatus, the light being mostly paid for in a lump sum at so much per day and per lamp. In smaller cities, where some control of the consumption is desirable,

so-called "current limiters" are installed, automatically interrupting the current at a certain fixed number of lamps simultaneously burning. The financial results of these works are extraordinarily favourable, dividends as high as 30 and 35 per cent. being very frequent. The enormous development of electric industry is, in the author's opinion, partly due to the installing of electric plants being unbounded by any rules; still, accidents are quite exceptional.—*Elektrot. Zeitsch., No. 45.*

Mining, Past and Future. **John A. Church.** It is only a quarter of a century since America contributed large amounts of copper and silver ores to the Welsh furnaces. These ores, gathered in desert regions, hauled by wagon routes to devious waterways, or by long rail journeys to a shipping port, were landed in Britain after a journey occupying in some cases from six to nine months. The beginnings of the great district at Clifton and Morneci were made when copper was hauled 600 miles in wagons, and when nearly a year was required to get a 4-ton locomotive on the ground. The freight alone on coke delivered at Globe amounted to 42 dols. per ton. These early necessities compelled a study of economy, the fruits of which have resulted in a considerable lowering of profitable grades of ore. For instance thousands of tons of copper ore of a metallic content lower than 2 per cent. are now smelted daily. A similar lowering of the profitable limit is found in silver ores, and whilst 30 years ago mines yielding less than 35 dols. per ton were considered unprofitable, preparations are now being made to mine ores worth only from 7 dols. 50 cents to 10 dols. per ton. It is noteworthy that the depression of the profitable limit in other ores does not obtain with iron, and it would appear that the average grade of iron ore now treated is higher than in the days of the charcoal furnaces. The improvements in iron manufacture have been in keeping with those of other branches of metallurgy, but these improvements, as far as the States are concerned, have not been a necessity of falling ore values.—*Mining Magazine, Vol. X, No. 1,* pp. 1–6.—*P. L.*

Carborundum Fire Sand. **T. J. Tone.** One of the most successful applications of this refractory material is as a lining for the various tilting or rotary oil melting brass furnaces. These furnaces have severe service conditions to meet, chiefly owing to the cutting action of the flames and the scouring slags produced, hence the necessity for a highly refractory material. Carborandum fire sand may be moulded into any required shape if mixed with silicate of soda to serve as a binder. An iron or wooden core is provided, and the material rammed between the core and the shell of the furnace. After drying, the furnace is ready for use, and the lining is stated to yield excellent results.—*Iron Trade Rev. Vol. XXXVII, No. 29,* p. 60.—*P. L.*

Test for Brittleness in Structural Steel. **J. P. Snow.** In devising this test, the author has had in view simplicity and speed. The latter is important, in that in many cases, stock cannot be held back until machine-finished samples are prepared and elaborate tests made. The test proposed is briefly as follows:—A piece about 12 ins. wide is sheared from the crop end of a plate and nicked 3 ins. from one edge preferably across the direction of rolling. One end is clamped in a vice and the free end bent over until fracture occurs, both vice and bending roller being actuated by hydraulic power. The nick is made by a tool having a raised bead on its face. It is believed that a test of this kind will detect brittleness by exposing the coarse grain due to improper heat treatment, segregation, or other defect. *American Society for Testing Materials, and Iron Trade Rev. Vol. XXXVII, No. 26,* pp. 40–42.—*P. L.*

The Structure of Metals and Alloys. **Percy Longmuir.** This paper is confined to the metallography of cast metals and alloys, and after describing the structures of pure metals, the influence of additions is considered. These additions may form with the metal a definite compound; or they may be held by the metal in the form of a solid solution; and in certain cases they may be present in the free state, as, for instance, the graphite of cast-iron. In the majority of cases compounds are formed, and by successive additions a point is reached at which free metal disappears and the whole of the structure is represented by the compound. Thus additions of zinc to copper result in the compound Cu_2Zn, and when a content of approximately 34 per cent. zinc is reached the mass is formed entirely by this compound. On exceeding 34 per cent. a compound richer in zinc is formed (Zn_3Cu), and an alloy containing 40 per cent. zinc is structurally composed of Zn_3Cu, distributed in a matrix of Cu_2Zn. Additions of carbon to iron result in a definite carbide (Fe_3C) or cementite. In normal mild steels cementite occurs in admixture with free iron or ferrite, and is then termed pearlite. At a content of 0·89 per cent. carbon the whole structure consists of pearlite; similarly at about 0·45 per cent. carbon the structure consists of crystals of ferrite and areas of pearlite in juxtaposition, each constituent being present in equal amount. Exceeding 0·89 per cent. carbon cementite crystallizes structurally free, being rejected to the boundaries of the pearlite areas. Thus a white cast-iron consists essentially of cementite and pearlite; on the other hand a grey cast-iron is structurally composed of graphite and pearlite and varying amounts of ferrite, if the combined carbon is below the saturation point, or of cementite if this point is exceeded. After describing the mechanical values of these structures, the influence of annealing is considered. In the case of steel castings the changes are purely structural, the value of which lies in an "interweaving" of the constituents one into the other. Annealing white cast-iron results in a chemical change, as shown in the decomposition of the hard and brittle cementite into ferrite and free carbon. This free carbon is amorphous; hence the high mechanical value of such a product.—*Manchester Conv. of British Foundrymen's Assoc., Aug. 2, 1904.*—*P. L.*

Molybdenum Steels. **Léon Guillet.** Two series of alloys have been prepared, the first containing about 0·2 per cent., and the second 0·8 per cent. carbon with molybdenum varying from nothing up to 15 per cent. With the first series after 10 per cent. molybdenum is exceeded the alloys will not forge, a similar point being reached in the second series at a content of 5 per cent. The micrography of these steels may be summarised as follows: — First series. Steels containing from 0·45 per cent. to 1·0 per cent. molybdenum present pearlite in a more divided condition than is usual with ordinary carbon steels. At 2 per cent. molybdenum a change of structure is noted, and pearlite whilst present is exceedingly fine. At 5 per cent. pearlite is absent, and the structure is characterised by a special constituent formed of long and fine filaments. — Second series. The pearlite of the second series is extremely divided, and at 1·2 per cent. molybdenum isolated white grains of the special constituent appear which increase with corresponding increments of molybdenum. At 10 per cent. molybdenum a eutectic formed by the special constituent and iron appears. The work indicates the special constituent to be a carbide, but its composition has not yet been determined. The micrography of molybdenum steels gives similar results to those of tungsten, but it may be noted that the structural transformations are obtained with a quarter the amount of molybdenum. In other words, molybdenum is four times as active as tungsten. The mechanical properties of the alloys tested are summarised in the table below. These results permit of the steels being divided into two classes according to their structure; thus Class I., steels of a pearlitic structure, and Class II., steels containing the special constituent (carbide). The pearlitic steels give high elastic limits and breaking loads with good reductions of area and normal elongations. They also offer a good resistance to shock, but are comparatively hard. Steels of the second class, are fragile, of a remarkable hardness, the latter property rendering them suitable for tool steels. In fine, the influence of molybdenum may be stated as similar to that of tungsten, one part of the former giving a similar result to four parts of the latter. *Revue de Métallurgie, July*, pp. 390–401.—*P. L.*

SERIES I.

Carbon.	Molybdenum.	Max. Stress.	Elastic Limit.	Elongation %	Reduction of Area %	Frémont Test. Kilogram-mètres.	Hardness. Brinell.
0·188	0·450	48·9	37·6	18·5	69·3	24	131
0·158	1·005	64·0	39·5	17·0	66·5	27	118
0·138	2·290	82·8	67·7	7·5	12·1	15	212
0·289	4·500	130·6	103·2	6·0	7·5	3	387

SERIES II.

Carbon.	Molybdenum.	Max. Stress.	Elastic Limit.	Elongation %	Reduction of Area %	Frémont Test. Kilogram-mètres.	Hardness. Brinell.
0·735	0·504	115·2	82·8	7·0	7·5	1	286
0·811	1·210	120·5	78·3	6·5	5·6	1	293
0·814	1·980	143·1	101·7	4·0	5·2	2	332